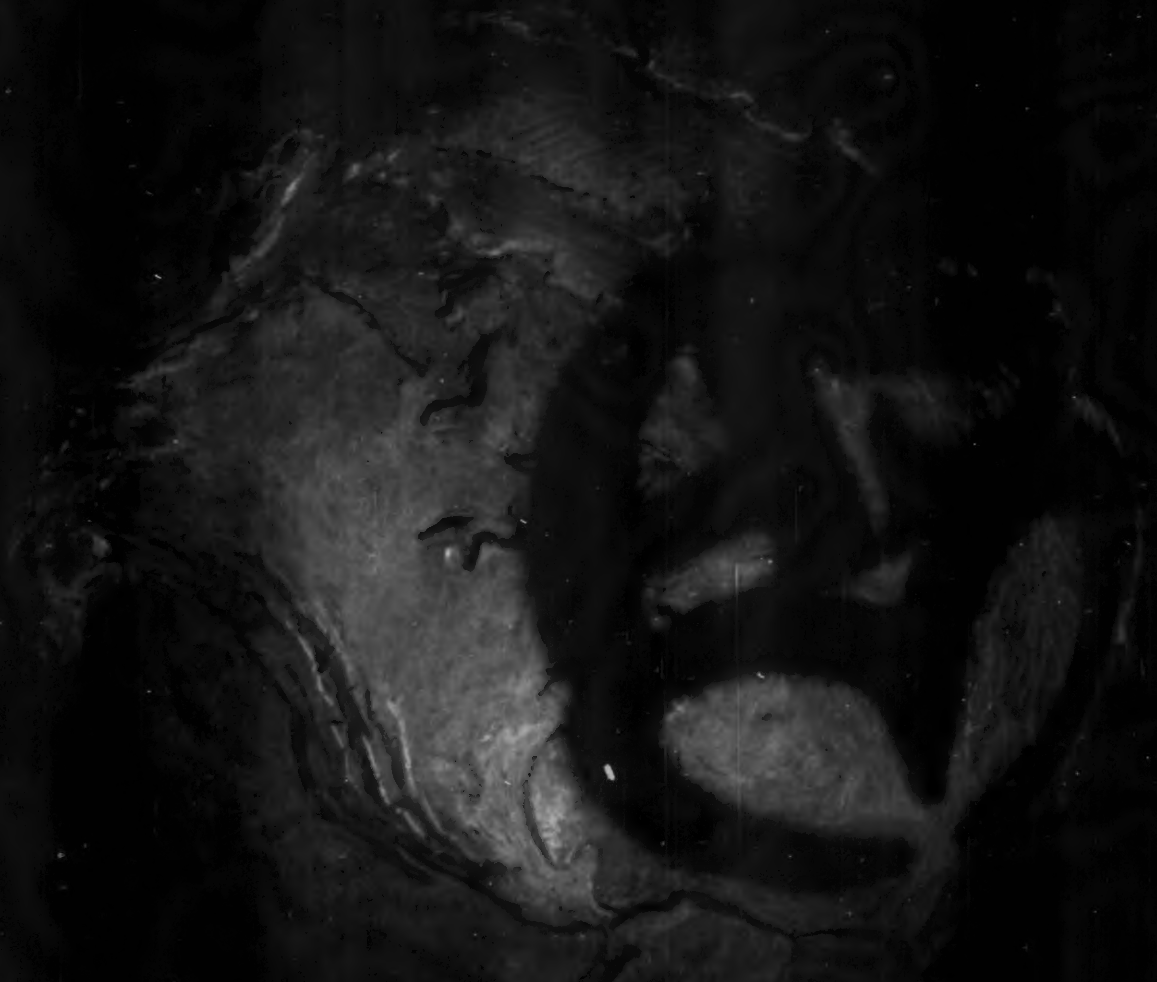
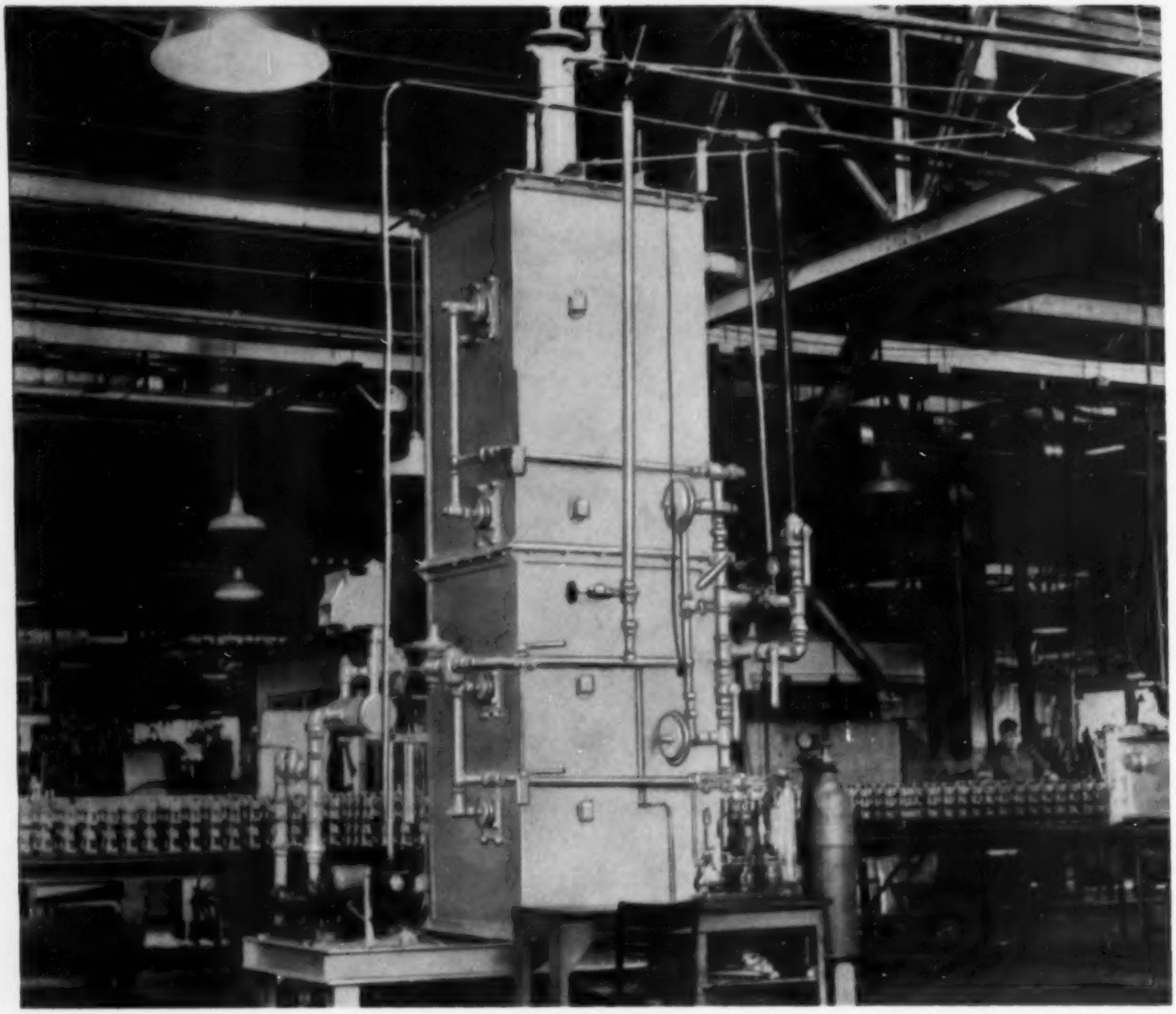
METAL PROGRESS



SEPTEMBER 1956



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Metal Progress

Volume 70, No. 3

September, 1956

Cover by JOSE VAZQUEZ

National Metal Congress and Exposition

Invitation 65

Technical Programs 66

The Congress and the sessions of the cooperating societies give such a variety of technical fare that the complete programs are presented morning by morning and afternoon by afternoon so the metals engineer may efficiently plan his week's schedule.

National Metal Exposition 85

Exhibitors, booth numbers and brief descriptions of products.

Engineering Articles

Economic Atomic Power Depends on Materials of Construction, by John H. Frye, Jr. and James L. Gregg 92

If metallurgists, ceramic engineers and chemists can produce the necessary constructional materials and low-cost uranium refining methods, a breeder reactor using uranium isotope 233 and a thorium blanket can generate heat at costs comparable to steam boilers using coal. (T25, U, Th, Al, Zr)*

Magnetite Concentrates to Supplement High-Grade Iron Ore, by E. C. Wright 97

As the high-grade Mesabi mines are being mined out, concentration of low-grade ore is coming ahead. One plant will make 3,500,000 tons of 63% iron pellets in 1956; another twice as large is under construction. (B13, B14, B16, Fe)

Materials in the Automobile of the Future, by A. L. Boegehold 103

The future family car will be no smaller than present models; it will weigh less because of generous use of light metals. The spark ignition gasoline engine will persist, but will be more efficient and lighter, even if more powerful. (T21)

Forming Sheet Metal Components for Aircraft, by John F. Tyrrell 110

Designs of aircraft change so rapidly that few sheet metal parts are ever produced in appreciable volume and some unique techniques have been developed to minimize retooling cost. (G general, SG-j)

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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The coding symbols refer to the ASM-SLA Metallurgical Literature Classification.

Metal Progress

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Recent Developments in the Art of Precision Casting, by Nicholas J. Grant 113

Time-tested processes using disposable patterns (wax, plastic or mercury) must compete with others using a thin-walled mold in which the casting solidifies quickly to a fine grain. (E 15)

Electric Versus Openhearth, by J. E. Wilbanks 118

Operating records in a cold metal shop having three 75-ton openhearths and two 75-ton electrics show that the latter can make steel faster and cheaper whenever scrap costs less than pig iron, and the product has equal or better quality. (D 2, D 5, ST)

Metal Powder Rolling – a New Fabrication Technique, by Samuel Storchheim 120

Wartime work in Germany on driving bands for artillery shells has been extended in America to 18-8 stainless steel and other powder metal combinations for manufacturing fuel elements for atomic power reactors. (H 14, Fe, SS, Al)

The Light Metals in American Economy, by Francis C. Frary 128

Did you know that only 10% of the aluminum made in the U.S. in 1955 went into aircraft, or that the largest single use of magnesium is as an alloying metal? Innumerable post-war applications have resulted from wartime experience. (T general, Al, Mg)

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A tabulation of the characteristics of 25 nuclear reactors in the U.S. supplements the article by Frye and Gregg on p. 92.

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Six committees of eminent scientists have reported to the National Academy of Sciences their studies of the effect of high-energy gamma radiation on genetics, pathology, weather and food supplies.

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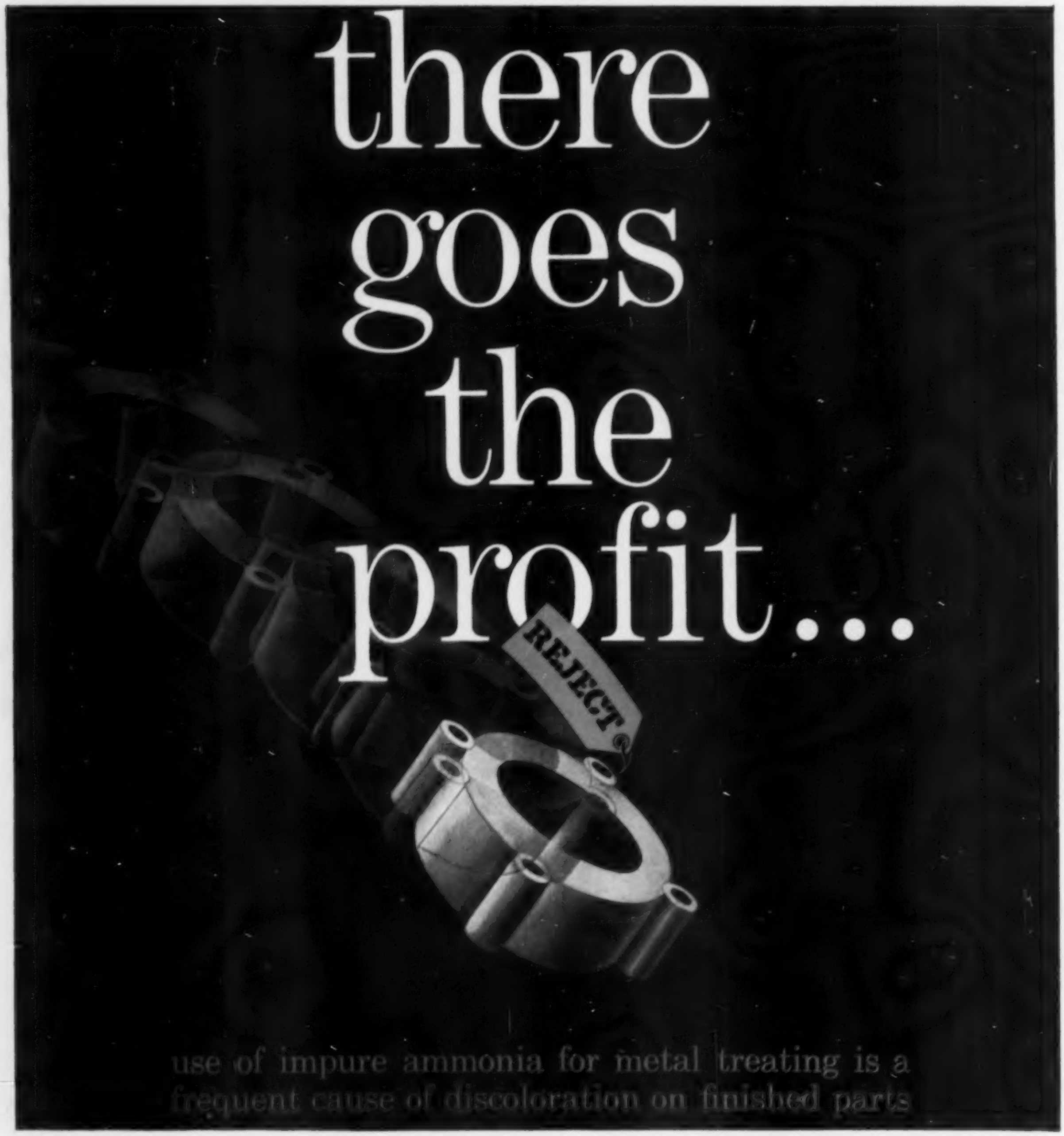

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As I was saying...

WHEN I was a youngster the time between one Christmas and the next seemed an interminable period – now it's here before you know it.

And so it's just one Big Congress and Show after another – and it's sure surprising how quickly the months fade away and here we are at another milestone. Cleveland is all agog about having the National Metal Congress and Exposition in its hospitable city and only regrets that it's short of adequate hotel accommodations. I might let you in on a little secret – if the Great Lakes Navigation and Steamship Co. were still in existence the A.S.M. would be in the hotel business again as we were at the Cleveland Convention some years ago when the 600-stateroom Greater Clevelander was tied up at the foot of Ninth Street to house A.S.M. members and guests during the Metal Congress and Exposition. If it cost $22,000 (in advance) to move the boat from Buffalo to Cleveland, how much would it cost today? The answer is *not* $64,000; that's the question.

You'll find the most complete and interesting program ever arranged by the A.S.M. The nine sessions of technical papers are all tops and have been selected by the Publications Committee with careful care. The A.S.M. Seminar on Saturday and Sunday on "Fatigue" is guaranteed to talk about it only – not to create it. The special session under the Industrial Heating Equipment Association, the two Educational Lecture Series, the Symposium on Thorium, the Special Clinic on Dies, the Annual Awards Luncheon on Tuesday, the 31 Alumni Luncheons on Wednesday, the Annual Banquet on Thursday, and the Distinguished Service Luncheon with "Young Engineers" as guests on Friday, and many other outstanding features will all combine to present seven days (and nights) ever to be remembered.

Let's not forget the Exposition using the entire capacity of Cleveland's mammoth convention halls where the 450 exhibitors will display their best and latest developments. Remember when we were able to "do" the show in one day? Not so anymore! It takes a minimum of two days in the show to "do" it well. It makes no difference what your problems are, you'll solve 'em quickly and correctly at the Metal Show.

Just completed contacting during the past chapter year and this summer all 96 chapters of the A.S.M. either individually or at regional groupings. The theme of the meetings was the planning of and for the 1956-57 chapter season. It was a fine report they were able to give of the past year – and a thrilling recital of the progressive steps planned for the coming year.

When all was said and done and the meetings over, I had forcibly impressed upon me again one fact that I recognized early in my association with A.S.M. and that was, "The Strength of the A.S.M. lies in its chapters and the chapters create that strength through the high character and unselfish service of the members of their executive committees."

A fact that was ever true.

See you all in Cleveland. It will be a pleasure.

Cordially,

Bill

W. H. EISENMAN, *Secretary*
American Society for Metals

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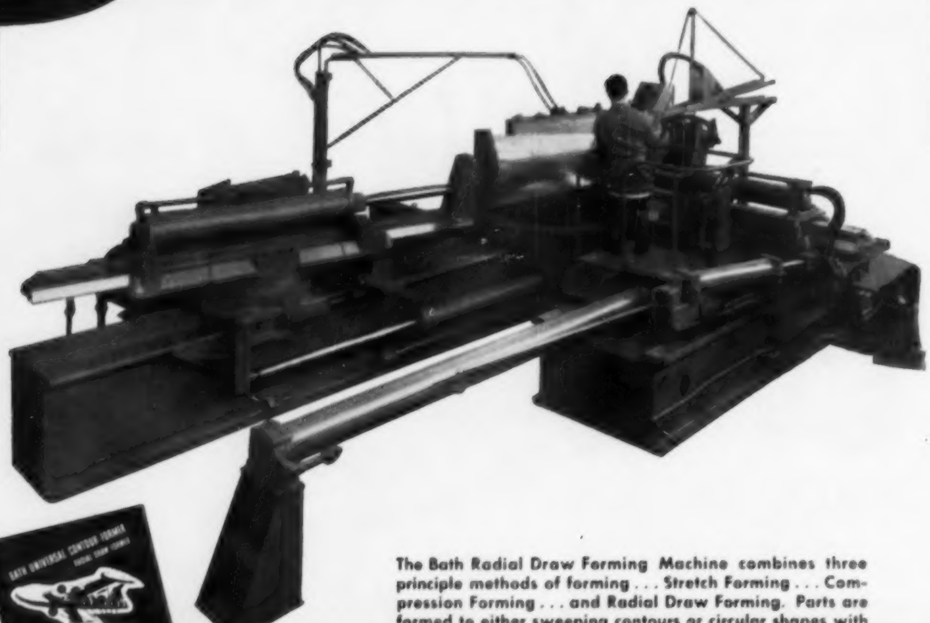

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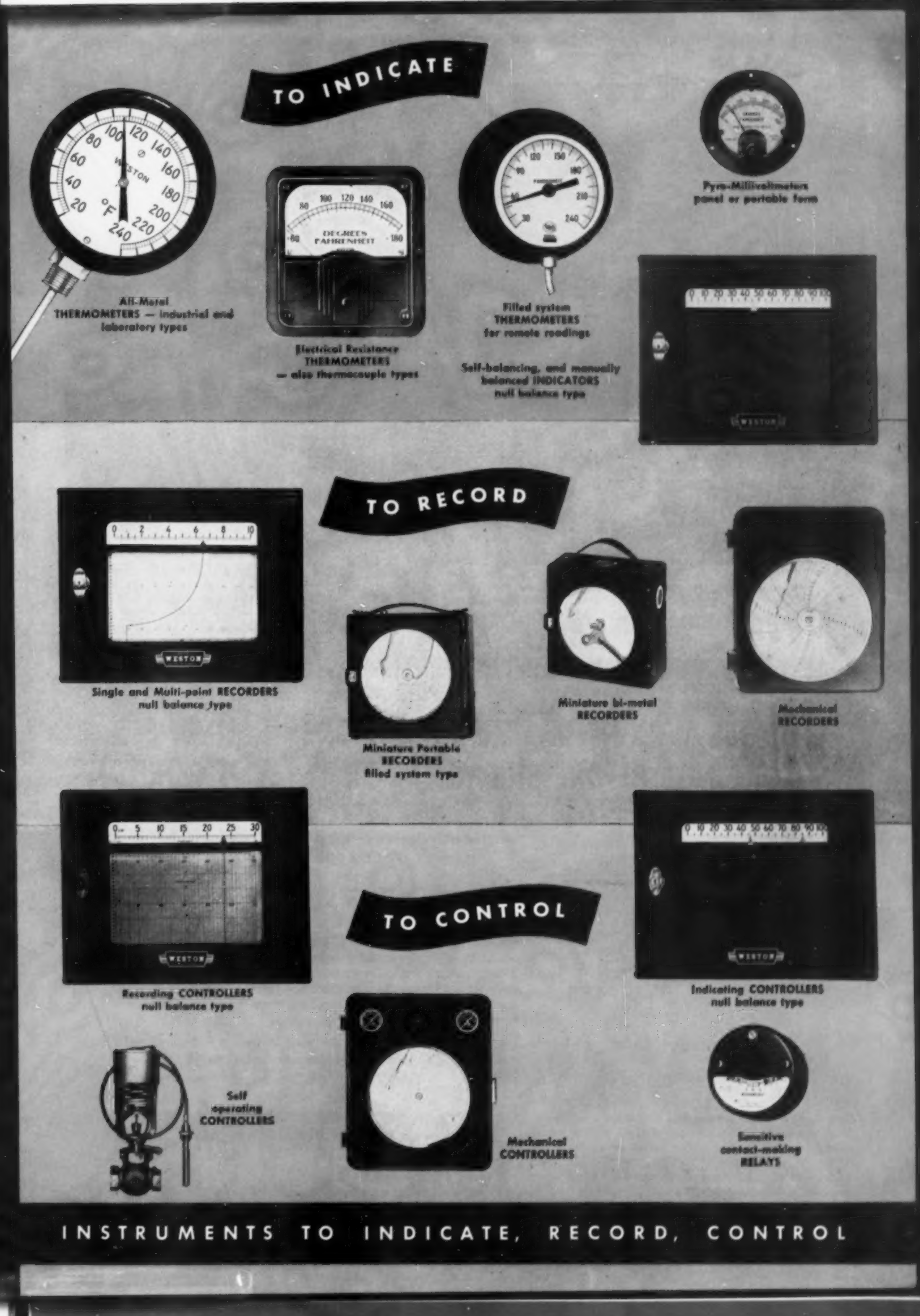
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INSTRUMENTS TO INDICATE, RECORD, CONTROL

SEPT. 1955

VOL. 3 NO.

NATIONAL CARBON COMPANY'S CARBON AND GRAPHITE NEWS

A COLD-CHARGE SHOP MOVES AHEAD

A COLD-CHARGE SHOP MOVES AHEAD

...with the electric arc furnace!

By R. S. Lynch, President
Atlantic Steel Company, Atlanta, Georgia

■ Any growing company must periodically make basic decisions concerning expansions of capacity, weighing carefully all the factors involved to insure continued growth and profitable operation.

Atlantic Steel, an all open hearth shop for 50 years, has increased melting capacity several times during that period. Again faced with the need for major expansion in 1951, the logical question was – further increase of open hearth capacity or installation of electric arc furnaces?

Through the years, as the chart on the facing page indicates, we had taken one step after another to increase the ingot capacity and efficiency of our open hearth facilities. In the postwar period, it became evident that we were approaching the limit of such measures and that a new capital investment was necessary. The decision we made was to invest in electric arc furnaces.

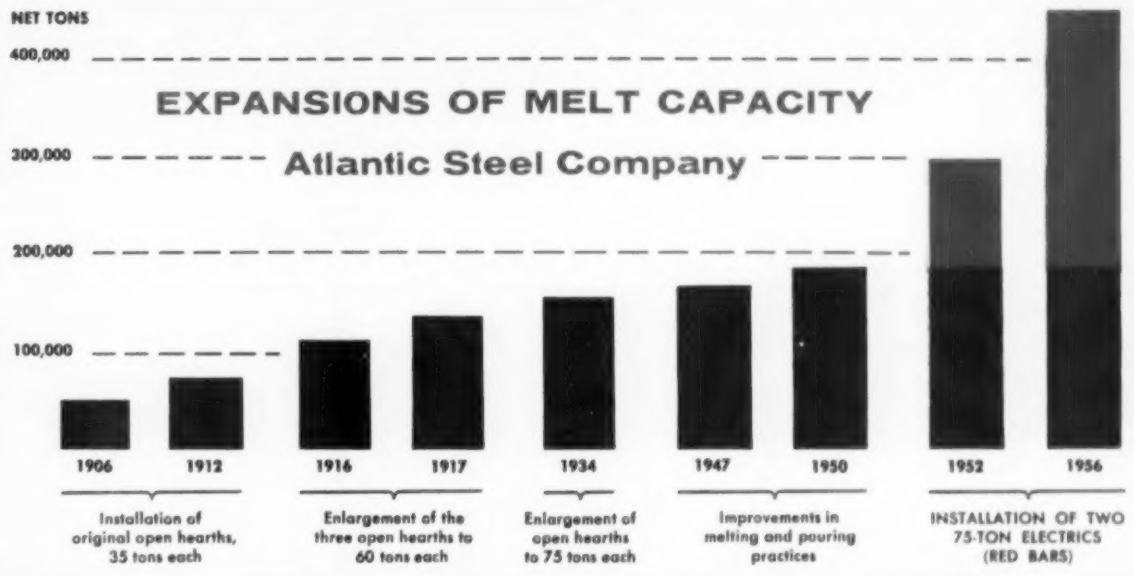
Several years of successful experience with our first 75-ton unit then dictated the installation of a second furnace.

Consequently, we now have acquired an ample basis for direct comparison of the electric against the open hearth on cold-melt, low carbon steel operations – making the same grades of steel, with the same personnel, and using the same raw material sources. The results of our experience show that our original decision was wise. The major advantages we have realized are:

LOWER FIRST COST. Our entire investment in the electric melt shop has been about 40% less than it would have cost to put in the equivalent open hearth capacity.

SAVINGS IN SPACE. Since our ground space is limited here in Atlanta, we appreciated the fact that the new melt shop, providing room for a total of three electric furnaces, takes up a third less space than would new open hearths producing the same tonnage.

FAST CONSTRUCTION. Each of our management decisions has been quickly transformed into new melting capacity. Because of the compactness, pre-fabrication and simplicity, an electric shop can usually be built more rapidly than an open-hearth shop of like capacity.



QUALITY CONTROL. Because our end-products require a wide range of carbon steel analyses, the electric furnace is particularly suited to our operation. Features important to us are precise temperature control and the absence of contamination from fuels.

FASTER HEATS. The four-hour heats of the electric furnace are a real boon to a custom shop such as ours. With adequate transformer capacity, we find that the only effective limitation on the heat input is the rate at which the scrap can absorb the heat.

FLEXIBLE OPERATIONS. We can produce electric steel according to demand – running the arc furnaces any number of shifts and any number of days per week. They start up quickly and shut down even more quickly, requiring the operator's attention only when producing steel.

LOWER OPERATING COSTS. Within six months after our first electric furnace was installed in 1952, it was producing steel at a lower net cost per ton than our open hearths which were working on the same grades. After the second furnace went into operation last fall, the economic advantage of the electric shop increased still more because of the reduction in its "cost above".

It should be emphasized that our shop produces no analyses outside of the low-carbon range – none of the high-priced alloy or stainless steels for which the electric furnace is usually required – yet we find that the arc has consistently reduced our costs and improved the efficiency of our operations.

We estimate that electric melting has reduced our ingot costs an average of 5%, compared to open hearth costs. Naturally, this figure varies somewhat with the cost of various raw materials. The cost advantage would also be different for other regions and end-products, but industry studies indicate that other non-integrated producers can also expect a substantial reduction of ingot costs with conversion to the electric furnace.

While on the cost factors, it is important to note that our power rates of 9-10 mills are neither high nor low as such rates go. Also, we have held our mold costs at about the same level as with the previous open hearth operation, by taking readings with immersion thermocouples to insure that electric furnace heats are not poured at excessive temperatures. And, we find that the electric furnace has reduced our costs for preparation of the scrap.

The flexibility and versatility of the electric shop are important operating factors to us because of the wide variety of our products. Since our founding, in 1901, to make cotton bale ties and turpentine barrel hoops, the list of products sold

under our trade-mark of "Dixisteel" has been steadily widened to include a complete line of merchant bars, reinforcing bars, fencing, nails, wire, small shapes and many other items. Hence the unusually wide variety of steel analyses — ranging from 5 to 40 points of carbon — and the extreme emphasis on flexibility in the Atlantic melt shop.

Some details of our electric shop experience may be of interest. We made the complete change-over with our regular open-hearth crews, excepting only an electric furnace melter hired from outside the company. Our personnel soon became skilled on the new furnaces and the training problems were minor, considering the scope of the change.

A most dramatic feature, of course, is the melting speed. The average heat cycle in our electric shop is four hours, but a good many heats approach the shop record of 2 hours and 45 minutes from charge to tap. The best heat we ever achieved with the open hearth was 7 hours, and our average was 8 hours. The slow charging operations on these open hearths made a painful contrast with the speedy top charging of our electrics. Our average output with open hearths ran about 8.5 tons per hour, but our electrics are running at almost twice that tonnage.

Another feature of the arc furnace which we find quite important is the ability to switch from single slag to double slag methods at will.

Our experience is 95% availability with the electrics where it was 90% with the open hearths.

New \$8½ million combination rod and bar mill — one of the world's fastest, with output of 5,000 feet of rods per minute and 40-50 tons of merchant bar products per hour — is part of Atlantic Steel Company expansion program.

Some reasons for the difference are obvious. A spare roof can be put in place in three hours. Complete relining, except for the furnace bottom, requires only 12 hours. As you might expect, our maintenance costs have been cut by more than 50%. Furthermore, it was our experience with open hearths that production began to drop off sharply toward the end of each furnace lining campaign, whereas the electric furnace maintains the high level of output throughout the life of a lining.

We see a great future for the electric arc melting of low-carbon "work-horse" grades of steel in bulk tonnages. And we look forward to the time when regional demand will require the installation of a third electric furnace, with proportionate expansion of other facilities.

Actually, such a time should not be so far away. We look forward to continued growth with plenty of competition to keep us on our toes and the electric melt shop to help us meet it on an equal basis.

To sum up the way we feel about our decision to install an electric melt shop, let me quote an experienced open hearth man who has gone through the entire change-over with us. J. E. Wilbanks, our Superintendent of Melting, says, "Electric furnaces can do everything that open-hearth furnaces can and do a better job of making quality steel at lower cost."

WHAT NATIONAL CARBON'S NEW SERVICE PROGRAM MEANS TO ONE ELECTRIC MELT SHOP

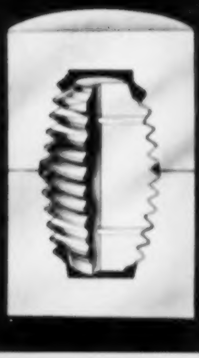
The TIMKEN Roller Bearing Company

■ April's Carbon and Graphite News announced the latest revision of a long-time National Carbon technical service – a concentrated electrode service program to help operators obtain the best possible electrode efficiency. This program, extending the company's customer service policy, is capsuled in a presentation of approximately an hour's duration. First given in Pittsburgh last December before the Electric Furnace Conference of the A.I.M.E., 38 customer meetings have been held by the National Carbon Electrode Service Group with enthusiastic response. The program is paying off in improved electrode performance, lower costs and an altogether better operator understanding of electrode operation.

For this interview, your Carbon and Graphite News Reporter has visited Timken Roller Bearing Company to bring you an on-the-spot discussion with Melting Superintendent, H. F. Walther; Assistant Melting Superintendent, L. D. Petersen; General Foreman, R. C. Roth; and First Helper, M. Podoliak. We asked these gentlemen to comment on the National Carbon program which had just been presented to a typical Timken melt shop group.

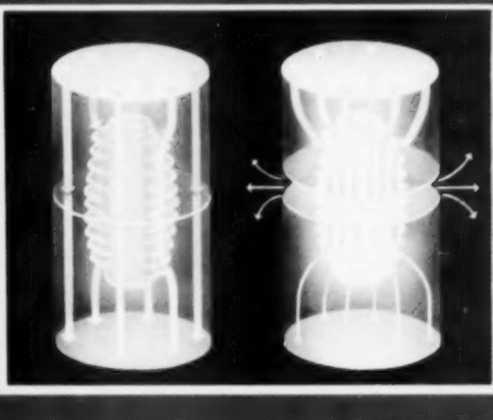
Q. Gentlemen, obviously from the group's response here tonight, you people are very much interested in electrode operation. We all know that electrode costs are an important consideration in electric furnace operation – do you feel that our program will help you reduce these costs?

A. Let's put it this way. Electrode costs and elec-



Pitch-reservoir* nipple keeps electrode joints tight.

*U. S. Patent No. 2735705



Good joining gives efficient current flow.

Open joint heats up nipple, causes breakage.

tric power costs are two major items in producing electric furnace steel which together account for about half of our "cost above".

We've been preaching this idea right along, so we were especially glad to hear your technical people emphasizing the do's and don'ts that make for best electrode performance at lowest cost. As a matter of fact, we'd say that if we could have reduced our electrode consumption as little as one half a pound per ton last year, we would have shown a cost reduction of approximately $80,000!

Q. That's an eye-opening observation – let's hope you'll be able to chalk up a cost reduction like this in the near future. Now, suppose you were to name one operational problem that stands out above all the rest, what would you pick?

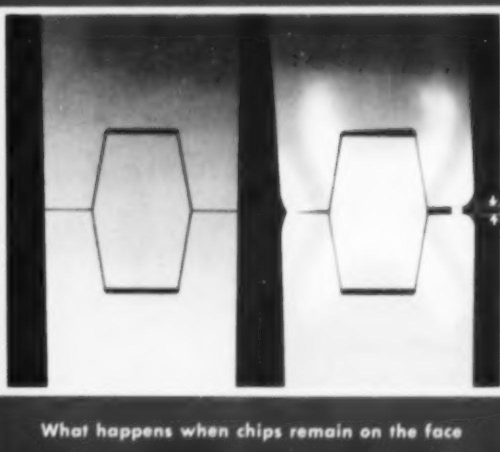
A. There are several, of course. Electrode breakage resulting from falling scrap can be one of the most troublesome, perhaps. At The Timken Company, we strive to avoid this by correctly placing our scrap within the furnace. We have emphasized to our people how improper scrap placement can lead to scrap "caves", and how this falling scrap can strike electrodes hard enough to break them. We were glad to see the importance you attached to this in your color slides and talk. Calling attention to the problem graphically like that helps our operating people visualize even better the necessity for placing heavy scrap on the bottom of the furnace – medium to light scrap above.

Q. A good portion of the time was spent here tonight discussing good joint-making procedure. Two points particularly seemed to stimulate a lot of interest: first, the importance of starting with a clean, chip-free end face and socket; and, second, the whys and wherefores of our recommendation that the connecting pin, or nipple, be added to the bottom of the old electrode rather than to the top of the new one. Would you like to comment on these points from your own experience?

A. Well, as to the matter of clean, chip-free end faces – it's easy to appreciate the desirability of maintaining maximum possible physical contact between the end faces of joined electrodes. Since ⅔ of the electric current goes through the end faces, we certainly want to avoid increased resistance at these interfaces. And, for the same reason, the sockets should be chip-free and clean so there will be no restriction between connecting pin and both sockets. It was good to hear you develop these thoughts further in your talk. Actually, that demonstrator unit of yours showed us more graphically than anything else we've ever seen just how seriously a lack of intimate electrical contact at the joint can affect electrode performance. It was easy for our men to associate the demonstrator's brightly glowing lamps with the unrestricted passage of current that results from a good, clean, tight joint. And, conversely, the dimly glowing lamps readily got across the idea of the poor passage of electrical current which occurs when joints are improperly made. You people must be receiving considerable comment from the field on this novel demonstrator unit.

Q. Yes, that's right–we're getting a lot of evidence that it's helping promote a better understanding

Use air hose for easy, sure removal of chips



What happens when chips remain on the face

of just what does take place at the electrode joint. And, it also helps operators understand some of the reasons for our recommended electrode handling practices. Perhaps there was some development touched on tonight that impressed you particularly — something you'd like to comment on?

A. One especially — we think one of the most significant developments in the electrode field in many years is your new pitch reservoir nipple. It has enabled such an improvement in joint-making practice that electrode and nipple breakage from unwinding has just about been eliminated in our shop. This has reduced electrode consumption.

You know, here at The Timken Company we were one of the first shops to recognize the potentialities of this new pin — and, we were one of the first to adopt it. Your cut-a-way color slide tonight showed our men exactly how the pitch in this new pin cokes under heat to lock the electrode joint firmly together. This was particularly well illustrated, we thought.

Q. Well, gentlemen — we certainly have appreciated the chance to meet with you here at Canton tonight and exchange ideas. As a parting shot, if you had to pinpoint the most valuable aspect of these meetings, what would it be — where would you say they're most helpful?

A. We think it's been a big help in two ways. First, your vivid presentation of the basic factors underlying our electrode costs has highlighted the problems our furnace crews face everyday. Second, there's no doubt, after the free give-and-take discussion here, that our men will put a lot of these basic ideas into practice, resulting in a long-term benefit to our company. In fact, we expect this will stimulate many more discussions of our own. Thanks for coming.

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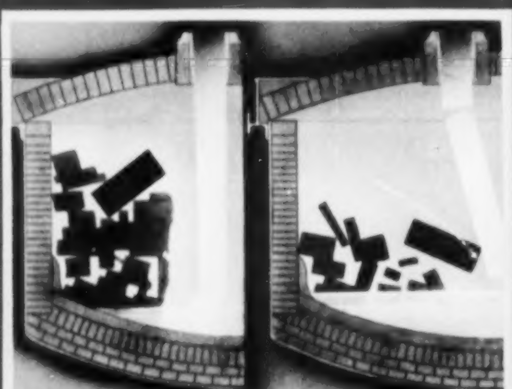
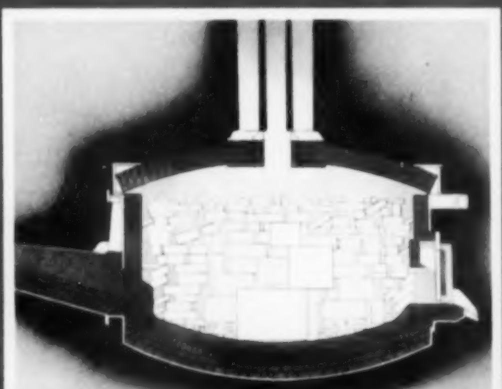


Effect of improper placement of the scrap



Proper positioning, heaviest scrap at bottom

APPLICATION and EQUIPMENT new products

Induction Heater

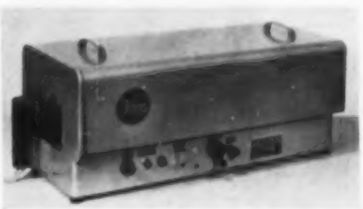
A completely redesigned induction billet heater has been announced by the Lombard Corp. Entire furnace operation is controlled by one push button. Any degree of taper or uni-

form heating is obtainable, with slight adjustments and coil construction is the same for aluminum, titanium, cupronickel or steel. Coils are cooled by water paths that are individually protected. No shut-down or warm-up time is necessary.

For further information circle No. 571 on literature request card, page 48-B.

Spectrometer

A new grating type scanning spectrometer has been announced by the Jarrell-Ash Co. Advanced optical design results in a first order reciprocal linear dispersion of 16 Å per millimeter at the exit slit, with a mini-

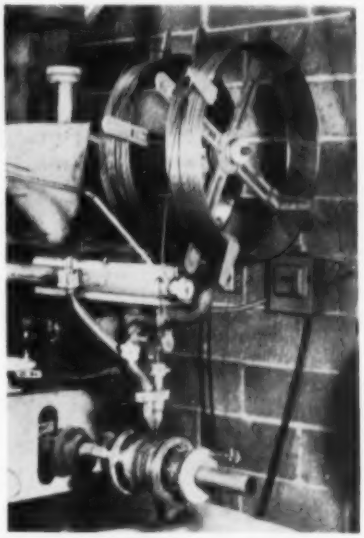


mum resolution of 0.2 Å. It is adaptable for use as a flame spectrometer, capable of detecting impurities to one part per billion. Among the features is a linear wavelength scanning mechanism which requires only a simple counter to indicate first order wavelength. A built-in 8-speed motor drive permits variable speed scanning in either direction, with manual drive also provided.

For further information circle No. 572 on literature request card, page 48-B.

Hard Surfacing

New copper-coated, alloy-filled wire, for automatic and semi-automatic hard surfacing has been announced by the McKay Co. The wire



produces chemically uniform welds comparable in performance to those of solid wire. It is available in ¼, 3/16, 5/32, ⅛, and 3/32 in. diameters. The illustration shows welding a hard surface overlay to a tractor roller.

For further information circle No. 573 on literature request card, page 48-B.

Thickness Measurement

A new X-ray fluorescence instrument permitting continuous determination of thickness of a metal coating to 0.000001 in. has been announced by Applied Research Laboratories. The three primary components of this equipment are the X-ray head, the high voltage source and the ratio recorder. X-ray head is a self-contained assembly including the X-ray tube and two detector heads. The high voltage source is a cased unit mounted next to the line. The ratio recorder comprises a strip chart recorder, ratio amplifier and high voltage Geiger supply.

For further information circle No. 574 on literature request card, page 48-B.

Titanium Descaling

Titanium forgings as well as other formed parts are now being descaled through the molten-salt-bath process, it has been announced by Kolene Corp. Advantages of the process in cleaning titanium aircraft forgings are: metal loss is reduced to a minimum, there is no etching and no hydrogen pickup, even when immersed for long periods of time. Parts such as aircraft turbine buckets and blades, which accumulate a heavy oily scale in service, are now being reconditioned by the process.

For further information circle No. 575 on literature request card, page 48-B.

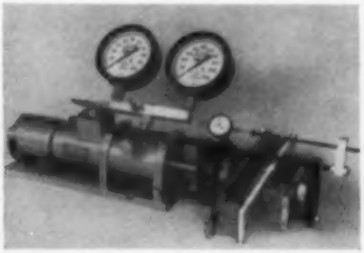
Measuring Microscope

A new measuring microscope which reads direct by vernier to 0.01 mm. on both the horizontal and vertical scales has been announced by the Ealing Corp. The instrument focuses by rack motion and has a 2 in. achromatic microscope objective, with a

focal length of 38 mm:, as standard equipment. It has a magnification of 33 times, an object field diameter of 2.0 mm. and a working distance of 45 mm. The new instrument will measure in either horizontal or vertical position.
For further information circle No. 576 on literature request card, page 48-B.

Tensile Testing

The Cal-Testing Machine Company has announced a new tensile testing device and fixture. Adaptable for ten-



sion, compression, or flexural testing when fitted with the proper accessories, the Cal-Tester provides a constant rate of strain and load for testing metallic or non-metallic materials in rod, strip or sheet form. The Cal-Tester has load ranges of 1000 and 5000 lb., divided into increments of 5 and 20 lb. on two 6 in. Bourdon tube gages. The unit is equipped with a precision shut-off control and automatic piston check to protect it from overloading or overtravel in either direction.
For further information circle No. 577 on literature request card, page 48-B.

Titanium Wire Cloth

Cambridge Wire Cloth Co. has announced the availability of industrial grades of wire cloth woven from titanium wire in mesh sizes ranging from 60 mesh down through the coarser sizes. It is intended for use in filtering or screening highly corrosive materials. In one instance, titanium cloth has been in service for more than 7 mo. with no evidence of corrosive attach whereas the previously used stainless steel cloth showed severe pitting after only 1 to 2 wk. of service.
For further information write No. 569 on literature request card, page 48-B.

Silver Plating

A new Silvrex bright silver plating process has been announced by Sel-Rex Precious Metals. Besides giving a mirror bright finish directly from the bath, hard (Brinell 135) and ductile deposits result. It operates at room temperature, has less fumes and less tendency toward bath decomposition. Range of current densities is from 10 to 40 amp. per sq. ft.
For further information write No. 570 on literature request card, page 48-B.

Heat Exchanger

A new type of impervious graphite heat exchanger for both heating and cooling nickel plating solutions has

been announced by Falls Industries, Inc. It consists of only three parts—a one-piece floating impervious graphite heat transfer cylinder, a one-piece header dome, and shell with required nozzles and mounting brackets. One unit in operation heats 7000 gal. of solution in 6 hr. from 95 to 160° F. During plating operations, this same exchanger is used to cool the bath.
For further information circle No. 578 on literature request card, page 48-B.

Plate Clamp

An electromagnetic plate clamp, designed to aid in industrial welding jobs, has been announced by Portomag, Inc. It is equipped with a ratchet lever jack, and a heavy duty (3000 lb.) magnetic pull, sufficient to

straighten out warped sheet steel. One of its most important applications is its use in plate alignment work for butt welding operations.
For further information circle No. 579 on literature request card, page 48-B.

Furnaces

A new line of oven furnaces for use in tensile, compression and bending tests has been announced by the Marshall Products Co. These furnaces are equipped with a fan at closed end of oven to provide air circulation and temperature uniformity. Viewing windows, hand holes and

other access ports are furnished to meet individual requirements. They are also available in various sizes and two different temperature ranges, 100 to 900° F. and to 1350° F.
For further information circle No. 580 on literature request card, page 48-B.

Degreaser

Circo Equipment Co. has announced a new metal parts degreaser for cleaning parts that have a tend-

ency to nest or pack, or parts that have recesses difficult to penetrate with a hand spray. The OP3 cleaning cycle is based on a consecutive boiling solvent, warm liquid and vapor dip and will remove tightly adhering greases, oils, tripoli and rouges.
For further information circle No. 581 on literature request card, page 48-B.

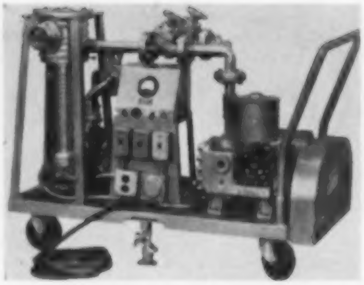
Controller

A new Series 500 air controller has just been announced by the Bristol Co. The controller is offered for measuring and controlling such variables as pressure, vacuum, temperature, liquid level, flow, differential pressure, and mechanical motion.

Control modes available include narrow band (on-off), proportional, reset, derivative, and reset plus derivative.
For further information circle No. 582 on literature request card, page 48-B.

High-Vacuum Pump

For general laboratory work, for pilot plant operations and small scale production applications, Kinney Mfg. Div. has announced a new portable high-vacuum pumping system. Designed to attain absolute pressures as low as 10^{-6} mm. Hg, the new mobile system employs a fractionating



4-in. diffusion pump, connected to a 15 c.f.m. two-stage roughing and backing mechanical vacuum pump. Service connections required are a single phase, 60 cycle, 110 to 115 volt a.c. outlet and a source of cooling water. The unit is recommended for use in exhausting 10 to 15 cu. ft. chambers for vacuum distillation, impregnation, coating, degassing and stress relieving.
For further information circle No. 583 on literature request card, page 48-B.

Creep Testing

Creep testing machine operation improved by modification of the electric contact-type extensometer has been announced by the Baldwin-Lima-Hamilton Corp. Two changes improve stability of the instrument. The electric contact arm is now supported by a rigid bar against which the arm is preloaded in bending in order to make a firmer contact than was possible with a free floating arm. In addition, the extensometer has been arranged for following either extension or contraction of test specimens by means of a two-position toggle switch in the drive motor circuit on the control panel of the machine.
For further information circle No. 584 on literature request card, page 48-B.

Welding Machine

Taylor-Winfield Corp. has announced a new spot and projection welder with a welding ram pressure device providing precise control of welding force and forging impact. Electronic control synchronizes application of impact with start of welding current, or impact may be delayed.
For further information circle No. 585 on literature request card, page 48-B.

Miniature Head for Thermocouples

The Marlin Manufacturing Corp. has announced a new screw type connection head for thermocouples, electric heating elements or swaged, magnesium oxide, insulated conductors. Stem sizes adaptable to the new con-

ductor head are 1/16 in., ⅛, 3/16, and ¼ in. These new sizes will provide a screw-type connection between the small gaged thermocouple wires and the larger gage lead wires. Operating temperature ranges to 500° F.
For further information circle No. 586 on literature request card, page 48-B.

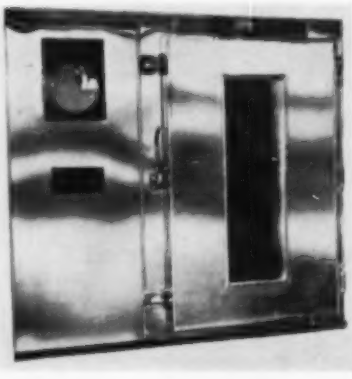
Hardness Testing

In order to meet the growing demand for a portable hardness tester with unlimited capacity to test large

specimens, the King Tester Corp. has produced a chain device adjustable to the size of the piece to be tested. High strength chromium-molybdenum steel arms hold chain to test head allowing test head to remain rigid while chain takes full thrust of load. Fast Brinell readings are obtained regardless of size or shape of parts tested.
For further information circle No. 587 on literature request card, page 48-B.

Temperature and Humidity Control

The Webber Manufacturing Co. has announced an automatic control of both temperature and humidity in its environmental test unit. In environmental test equipment which requires control from −80 to +200° F., and 20% to 90% relative humidity, ac-



curacy can be held to ±1½%. The control system followed a predetermined cycling time. High-low temperature, humidity and cycling control are available to meet any requirements.
For further information circle No. 588 on literature request card, page 48-B.

Rolling Mill

This combination 2-high 4-high rolling mill has been developed by Stanat Mfg. Co. It is employed as a utility

mill for the experimental rolling of small pieces at the Babcock & Wilcox Co.'s Nuclear Facilities plant. Ingots are heated between passes in the electric furnace at the left.
For further information circle No. 589 on literature request card, page 48-B.

Hot Salt Pump

Ajax Electric Co. has announced a new air-driven hot salt pump designed especially for pumping molten salts and hot metals. The pump is powered by an air-driven motor which is self-cooling. The pump body is made of a limited number of sturdy parts designed for operation under high ambient temperatures. Available in steel or with stainless steel submerged parts

(for temperatures over 1000° F.), the pump has a maximum flow capacity of about 36,000 lb. an hour using 90 psi. air pressure.
For further information circle No. 590 on literature request card, page 48-B.

Germanium Rectifier

A new line of germanium electroplating rectifiers has been announced by Wagner Brothers. They utilize the new General Electric germanium "safety cell" hermetically-sealed to protect the germanium wafer from the deteriorating effects of moisture and corrosive fumes. Basic stacks consist of six germanium cells, each with cooling fins. The stacks are of a standard design, are interchangeable, and are rated at approximately 500 amperes each. Every germanium cell is individually protected against circuit fault conditions and sudden overloads by fuses which break circuit. All units are forced air cooled, being equipped with an extra-capacity centrifugal blower.
For further information circle No. 591 on literature request card, page 48-B.

Nickel Plating

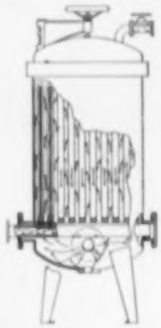
A new nickel plating process for use with their bright rhodium has been announced by Sel-Rex Precious Metals. The new process counteracts rhodium electroplate's tendency to cracking and peeling, when used as an undercoat.
For further information circle No. 592 on literature request card, page 48-B.

Cleaner

A new cold cleaner for spray washers has been announced by Klem Chemicals. This cold cleaner is a one package compound which is added to water 1½ to 3 oz. to 1 gal. of water and is ready for use. It removes all types of soil including cosmaline-type rustproofing compounds. Foaming has been controlled.
For further information circle No. 593 on literature request card, page 48-B.

Vertical Filter

A number of new devices to increase filtering performance and convenience on vertical filters have been announced by Industrial Filter & Pump. Filter leaves that can be lifted from the manifold without unbolting, bottom and top outlet leaves, quick opening cover, jacketed shell, bottom opening filter chamber and individual leaf outlets are featured.



For further information circle No. 594 on literature request card, page 48-B.

Burnishing Compound

A new alkaline burnishing compound for zinc die castings has been announced by Oakite Products. Oakite FM 186 is an alkaline liquid

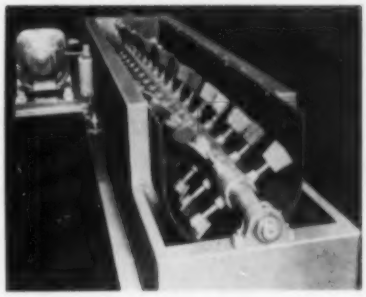
compound which may be used for self-tumbling or with shot or synthetic media. Recommended concentration of the solution is 1 to 2% by volume. Its use is said to produce a brighter finish and to improve the color of zinc die castings. It is also recommended for burnishing steel and copper.
For further information circle No. 595 on literature request card, page 48-B.

Load Cell

Miniature SR-4 load cells for electrical measurements of forces and weights up to 10,000 lb. in compression have been announced by Baldwin-Lima-Hamilton Corp. These cells are less than 2 in. in diameter and only 2¾ in. high. They were developed to measure thrust forces in large steam turbines but may be used wherever space is too limited to permit use of standard cells of larger size. Calibration accuracy is within ±0.25% of full range at any load at 70° F.
For further information circle No. 596 on literature request card, page 48-B.

Mixers

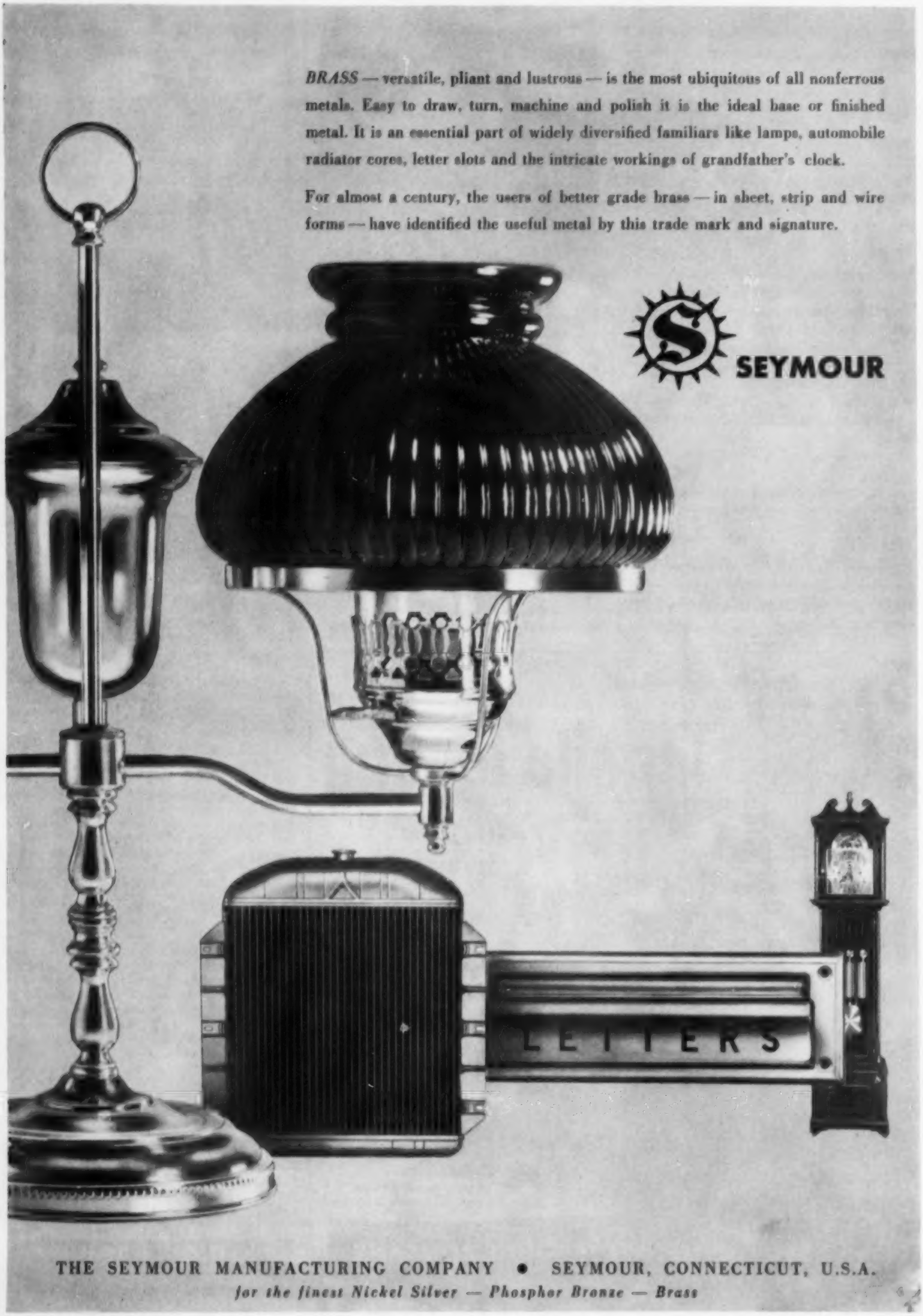
A new line of continuous mixers has been announced by the Gas Machinery Co. They will handle any size material from dust to 1½ in., either dry or in a slurry. All welded frame of heavy steel plate, standard replaceable mixer trough of heavy gage material, box-type construction are some features of the mixers.



For further information circle No. 597 on literature request card, page 48-B.

Brinell Microscope

The King Tester Corp. has announced its new line of Brinell scopes. Made of stainless steel, they are compact, lightweight and rugged. The lens has a patented 3-way construction and needs no adjustment to the eye. The microscope has a large opening in the side to utilize natural light and in addition, it has built-in illumination.
For further information circle No. 598 on literature request card, page 48-B.


BRASS — versatile, pliant and lustrous — is the most ubiquitous of all nonferrous metals. Easy to draw, turn, machine and polish it is the ideal base or finished metal. It is an essential part of widely diversified familiars like lamps, automobile radiator cores, letter slots and the intricate workings of grandfather's clock.
For almost a century, the users of better grade brass — in sheet, strip and wire forms — have identified the useful metal by this trade mark and signature.
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APPLICATION and EQUIPMENT new literature

631. Brazed Tubing
12-page data book on brazed tubing made from copper coated steel. *Bundy*

632. Brazing
8-page bulletin S-1050 on production brazing and soldering. Automatic brazing machine. *Selas Corp.*

633. Brazing
16-page pocket-sized guide to selective fluxing for low temperature silver brazing. *American Platinum*

634. Brazing
Low Temperature Brazing News, No. 73, gives case histories. *Handy & Harman*

601. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it may be used with and parts that may be cleaned. *Globe Steel Abrasive*

602. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

603. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

604. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

605. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

606. Alloy Tools
44-page book on cast Stellite tools for metal cutting. *Haynes Stellite*

607. Alloy Tubing
Data Card 184 on carburizing, heat treatments, critical points, mechanical properties, welding and machining of 4100 series steel tubing. *Babcock & Wilcox*

608. Alloys
8-page bulletin on composition, properties and applications of series of 12 copper-nickel-base alloys available in cast form. *Waukesha Foundry*

609. Aluminized Wire
6-page booklet on aluminized steel wire and its applications. *American Chain & Cable*

610. Aluminum Bonding
Brochure on Alumi-coat process of bonding aluminum and its alloys to ferrous metals. *Arthur Tickle Eng'g. Works*

611. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

612. Aluminum Extrusions
Data on commercial aluminum extrusions. *Superior Industries*

613. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

614. Annealing
Reprints of article on continuous annealing of stainless steel sheets in roller hearth furnace. *Gas Machinery Co.*

615. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

616. Arc Furnaces
Flexibility of the electric arc furnace—what it means to the steel producer, in Carbon and Graphite News. *National Carbon*

617. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

618. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

619. Atmosphere Furnaces
4-page bulletin on furnaces for hardening high carbon and high speed tool steels. Diagrams, specifications and performance data. *Lindberg Engineering Co.*

620. Atmospheres
12-page bulletin on use of protective atmospheres to prevent deterioration of metals during various heat treating processes. *General Electric*

621. Atmospheres
Bulletin on generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co.*

622. Atmospheres
12-page booklet on design and use of special atmospheres for industrial furnaces. *Continental Industrial Engineers*

623. Bearings
20 data sheets give special properties and case histories for new Rulon oil-free bearing material. *Dixon Corp.*

624. Bearings
Chart on chemical, mechanical and work characteristics of sintered bronze or iron bearing materials. *Bound Brook Oil-Less Bearing*

625. Beryllium Copper
4-page data sheet features a section detailing the specific methods for heat-treating beryllium copper. Engineering specifications including physical properties and the effect of these properties on heat treatment. *American Silver Co.*

626. Beryllium Copper
6-page booklet 7 on precision strip for electronics applications. Table of typical mechanical properties of beryllium copper, phosphor bronze, nickel silver, brass, gilding metal, chromium copper and stainless. *Penn Precision Products*

627. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

628. Blast Cleaning
New 8-page brochure No. 607 on air blast cleaning cabinet. Tables give dimensions and specifications. *Pangborn Corp.*

629. Blast Cleaning
Booklet on airless abrasive cleaning of shell molded castings for removal of sand, scale, discoloration and grinding lines. *Wheelabrator Corp.*

630. Brass
20-page pocket-size booklet on brass rod mill products. Weight tables, specifications and other technical data. *Titan Metal Mfg. Co.*

600. Cemented Carbides

"Designing with Kennametal" is a new booklet prepared specifically for design engineers. It begins with a discussion of basic design principles. The section on fastening by brazing discusses such topics as relieving

braze strains, shrink brazing circular parts and shape of brazed joints. In addition, sections on cementing, mechanical fastening and finishing are included. The booklet concludes with a discussion of typical design problems and applications. The 44-page booklet is well illustrated and attractive. *Kennametal, Inc.*

635. Brazing
Bulletin 5889 on furnace and induction brazing installations and methods. *General Electric*

636. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

637. Bright Annealing
6-page bulletin describes furnaces for annealing system for nonferrous metals. *Lee Wilson Engineering*

638. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

BLAST FURNACE downcomer linings being gun-applied with Lumnite-concrete at Pittsburgh Works, Jones & Laughlin Steel Corp. Inset (left) shows blast furnace downcomer system lined with Lumnite Industrial Concrete.

Protect downcomer systems with Industrial Concrete linings

Abrasion and heat put Lumnite-concrete linings to the test in these big blast furnace downcomers. But once "shot" into place, Lumnite* gives long-lasting, smooth, jointless linings that effectively withstand rugged service conditions. If repairs are needed, they can be made quickly and easily—because Lumnite-concrete reaches service strength within 24 hours.

Such linings are just one of the many profitable uses for Lumnite calcium-aluminate cement in blast furnaces. Use it also for **Heat-Resistant** foundation pads in blast furnaces and stoves; **Refractory** linings in hot blast mains, where the easy placement of Lumnite-concrete simplifies the once intricate job of forming Y-intersections; Refractory Concrete **insulation** for stove domes; and for many other jobs where high-temperature service up to 2600°F. and durability are needed.

Keep a supply of Lumnite cement or prepared Lumnite-base castables on hand for emergency needs. Packaged castables containing Lumnite cement and selected aggregates assure the right concretes for a wide variety of high-temperature applications. Castables are made and distributed by leading manufacturers of refractories.

UNIVERSAL ATLAS CEMENT COMPANY

UNITED STATES STEEL (US) CORPORATION SUBSIDIARY

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639. Burners
New bulletin and data sheet on series 214 burners give advantages, capacities, specifications. *North American Mfg.*

640. Burners
8-page Bulletin SC-1004 on ribbon burner describes burners, heating techniques and gives selection data. *Selas*

641. Burners
Bulletin on pulsation-type oil-gas burner for annealing furnaces, baking ovens, billet heating, heat treating and forging furnaces and many others. *Radiant Products Co.*

642. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

643. Carbon Analyzer
8-page booklet on equipment for hydrogen and carbon determination in titanium, zirconium, iron, steel and heat resisting alloys. *National Spectrographic Lab*

644. Carbon Brick
Bulletin on properties, grades, applications of carbon and graphite brick for handling corrosive chemicals and molten metals. *National Carbon*

645. Carbon Dioxide Welding
12-page reprint on carbon-dioxide shielded consumable electrode arc welding. Methods of supplying and flow characteristics of carbon dioxide. Properties of weld metal, operating characteristics. *Air Reduction*

646. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

647. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

648. Castings
Literature on shell or sand castings of ArmaSteel, malleable iron or gray iron. *Central Foundry Div.*

649. Ceramic Tools
10-page report on machining steel with ceramic tools includes grinding ceramic tools, new-type tool holder, geometry of ceramic tools. *Norton*

650. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

651. Chromium Plating
New folder gives advantages of new additive. Tables of compositions of plating solutions. Charts. *Diamond Alkali*

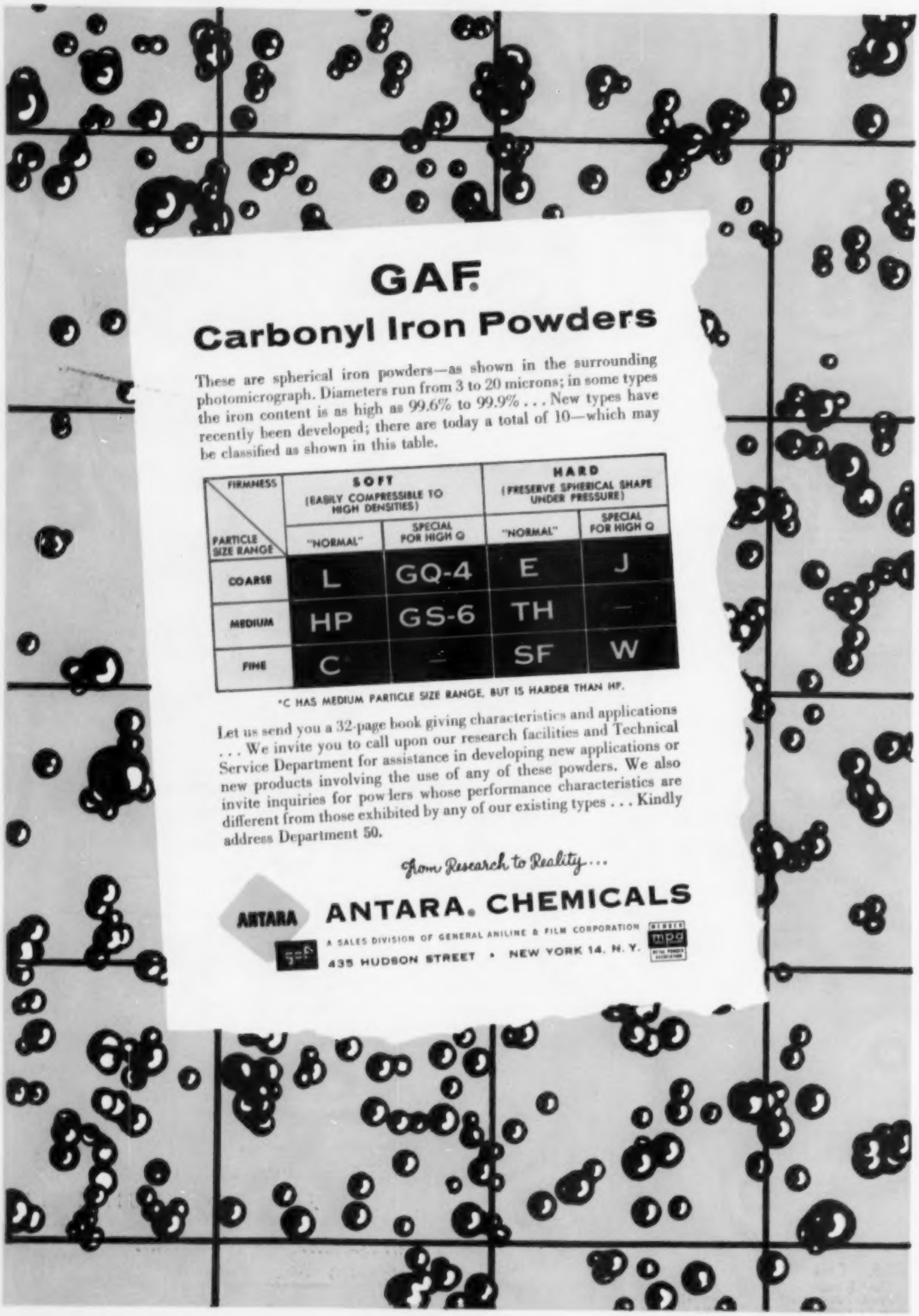
652. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

653. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

654. Cleaners
New 4-page bulletin on cleaners for preparing metallic surfaces for electroplating, anodizing, painting. *Hanson-Van Winkle-Munning*

655. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning", discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

656. Cleaning
New 8-page bulletin on cleaning machines. Importance of mechanical agitation in parts cleaning. *Magnus Chemical*



GAF

Carbonyl Iron Powders

These are spherical iron powders—as shown in the surrounding photomicrograph. Diameters run from 3 to 20 microns; in some types the iron content is as high as 99.6% to 99.9% . . . New types have recently been developed; there are today a total of 10—which may be classified as shown in this table.

FIRMNESS / PARTICLE SIZE RANGE	SOFT (EASILY COMPRESSIBLE TO HIGH DENSITIES)		HARD (PRESERVE SPHERICAL SHAPE UNDER PRESSURE)	
	"NORMAL"	SPECIAL FOR HIGH Q	"NORMAL"	SPECIAL FOR HIGH Q
COARSE	L	GQ-4	E	J
MEDIUM	HP	GS-6	TH	—
FINE	C*	—	SF	W

*C HAS MEDIUM PARTICLE SIZE RANGE, BUT IS HARDER THAN HP.

Let us send you a 32-page book giving characteristics and applications . . . We invite you to call upon our research facilities and Technical Service Department for assistance in developing new applications or new products involving the use of any of these powders. We also invite inquiries for powders whose performance characteristics are different from those exhibited by any of our existing types . . . Kindly address Department 50.

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ANTARA. CHEMICALS

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657. Cleaning
New 8-page booklet on wetting agents, detergents, emulsifiers. *E. F. Houghton*

658. Cleaning Solvent
New 4-page folder on detergent-action safety solvent. Uses, advantages. *Turco Products*

659. Coatings
4-page bulletin on how pure metallized zinc or aluminum coatings prevent corrosion. Typical applications. *Metallizing Engineering Co.*

660. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

661. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

662. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

663. Continuous Casting
24-page book, "Better by the Mile", describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

664. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

665. Controllers
16-page educational bulletin No. 9 gives data, operation diagrams, schematic drawings of capacitrols. *Wheelco*

666. Controllers
80-page catalog 8305 on nonindicating electric, electronic and pneumatic controllers for temperature, pressure and humidity. *Minneapolis-Honeywell*

667. Controllers
12-page booklet on temperature controls and special purpose controllers. Operation, design, installation. *Assembly Products, Inc.*

668. Copper Alloys
40-page book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

669. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

670. Corrosion Prevention
Full technical details on Turcoat 4178 aluminum conversion coating that stops corrosion of aluminum, improves paint adhesion and provides an ornamental finish. *Turco Products*

671. Corrosion Resistance
20-page bulletin on copper alloys for corrosion resistance. Table gives applicability in 150 media. *Ampco*

672. Creep Testers
Data file lists 8 models, gives salient features, and illustrates them and uses. *Arcweld Mfg.*

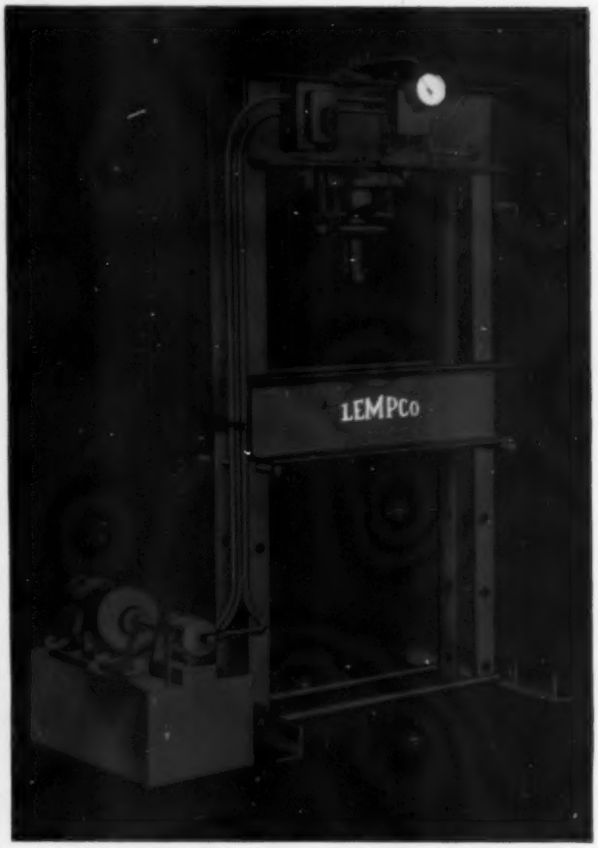
673. Creep Testing
Bulletin 4420 describes long-time creep test machines, creep-rupture machines and relaxation machines. *Baldwin-Lima-Hamilton*

674. Crystal Models
Folder describes unique kit for constructing crystal models. *Harshaw*

675. Cut-Off Wheels
36-page revised manual on cut-off machines and abrasive wheels. *Norton Co.*

Compare

these BEST BUY Lempco press prices with prices of other producers:



Model 50-E, 50-Ton Electrically Operated Hydraulic Press

Lempco Model No.	25M	50M	75M	100M	150M
Rated Tonnage	25	50	75	100	150
Press Operation	MANUALLY OPERATED				
*LEMPCO	$315	$440	$550	$1140	$1200
Competitor "A"	370	631a	679b	(X)	1405
"B"	375	515	645	1430	1650
"C"	(X)	565a	695	1365	1690
"D"	386	591	788	1541	(X)

Lempco Model No.	25 E-2	50 E-2	75 E-2	100 E-2	150 E-2
Rated Tonnage	25	50	75	100	150
Press Operation	2 H. P. PUMP UNIT				
*LEMPCO	$825	$875	$1050	$1720	$1920
Competitor "A"	(X)	(X)	(X)	(X)	(X)
"B"	1430	1430	1650	(X)	2640
"C"	(X)	(X)	(X)	(X)	(X)
"D"	1147c	(X)	(X)	(X)	(X)

*Prices effective April 15, 1956 . . . F.O.B. Lempco Plant, Bedford, Ohio . . . Prices subject to change without notice.

Lempco Model No.	25 E-7	50 E-7	75 E-7	100 E-7	150 E-7
Rated Tonnage	25	50	75	100	150
Press Operation	7-1/2 H. P. PUMP UNIT				
*LEMPCO	$1150	$1200	$1380	$2050	$2250
Competitor "A"	(X)	(X)	(X)	(X)	(X)
"B"	(X)	(X)	(X)	(X)	(X)
"C"	(X)	1586	1716	2428	2713
"D"	1375c	1414	1623	2402	(X)

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NOTE:

HYDRAULIC PRESS PRICE COMPARISONS ARE FOR EQUAL OR CLOSELY SIMILAR SPECIFICATIONS. (X)—No Model Listed; a—60-Ton Listed; b—80-Ton Listed; c—30-Ton Listed. Entries Indicate Nearest Reasonably Equal Specification Known to be Offered. Prices and Specifications are Effective, to the Best of Our Knowledge, on or about April 15, 1956.

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676. Cutting Oil
Bulletin 39 on transparent cutting oil which is designed for use on a wide variety of steels. *Sun Oil Co.*

677. Cutting Tools
36-page booklet analyzes and compares carbon, high speed, cast alloy and carbide tool materials. *Allegheny Ludlum*

678. Cyaniding
Production pot cyaniding with mechanical dump and load is described in the April issue of Metal Minutes. *Sunbeam*

679. Decarburization
8-page booklet on effects of decarburization on tool steels tells what it is and what can be done about it. *Carpenter Steel*

680. Descaling
24-page book, "Handling Metallic Sodium" with special reference to sodium hydride descaling. *U.S. Ind. Chem.*

681. Descaling
16-page bulletin 608 on how Rotoblast descaling machine operates, outstanding features, examples of its use. *Pangborn*

682. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

683. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

684. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

685. Diamond Polishing
8-page booklet on metallographic polishing with diamond abrasive and its advantages over silicon carbides. *Elgin National Watch Co.*

686. Die Casting
New illustrated catalog on complete line of die casting machines. *Kux Machine*

687. Die Sets
Catalog shows complete line of ball bearing die sets. *Lempco Products*

688. Electric Furnace
Bulletin on box-type, pre-heat and hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

689. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

690. Electric Furnaces
Bulletin 441 on box-type electric furnaces diagrams and describes the furnaces and lists specifications. *Hevi Duty Electric Co.*

691. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

692. Electrocoated Wire
8-page bulletin on new wire materials —Nickelply and Brassply, electrocoated steel wire. How it may be formed, bent and twisted without breaking the coating. *National Standard*

693. Electrodes
16-page catalog of complete line of spectroscopic electrodes and powders. 37 special grade preformed electrodes illustrated and described. *National Carbon*

694. Electrodes
Folder describes two electrodes recommended for welding cast iron. *Metal & Thermit*

695. Electrodes
4-page bulletin describes characteristics, properties and sizes of five grades of bronze electrodes. *Ampco Metal*

696. Electrolytic Metals
New 4-page folder on analysis and specifications of electrolytic chromium and manganese. Uses and properties. *Electro Metallurgical Co.*

697. Electron Microscope
20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

698. Electron Tubes
Catalog lists 67 types of electron tubes, describes them, gives general characteristics and maximum ratings. *Machlett*

699. Extruded Products
6-page folder covering extruded products. Diagrams of Ugine-Sejournet hot extrusion process. Alloys which may be successfully extruded. *Babcock & Wilcox*

700. Ferro-Alloys
32-page book tells how ferro-alloys are made and how they are used. *Electro Metallurgical Co.*

701. Filters
32-page booklet on filters, mixers, pumps and tanks for liquid processing. *Alsop Engineering*

702. Firebrick
28-page bulletin R-34 on properties and characteristics of 5 kinds of firebrick. Typical applications. Tables of brick quantities for arches of different sizes and shapes. *Babcock & Wilcox, Refractories Div.*

703. Flame Hardening
20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

704. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

705. Fluoroscopy
12-page booklet on fluoroscopy for nondestructive internal inspection. Explains image amplifier. *Westinghouse Electric, Industrial X-Ray Dept.*

706. Forging Hammers
24-page brochure describes construction and use of steam drop hammers. *Erie Foundry*

707. Forging Machinery
32-page book No. 165 on design of dies for upsetting forging machines also includes machines, representative parts, tables of decimal equivalents and areas of circles. *Ajax Mfg. Co.*

708. Forgings
Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U.S. Steel*

709. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

710. Forgings
8-page booklet, "What Is a Forging?", on how forging idea originated and grew, how forgings are made and importance of forgings in modern products. *Drop Forging Assoc.*

711. Forming
86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

712. Forming
Contract forming catalog on complete contract facilities. Draw forming equip-

ment and conventional equipment. *Cyril Bath Co.*

713. Furnace Belts
New 42-page booklet on alloy steel belts for continuous high-temperature furnaces. Belt selection guide. *Wickwire Spencer Steel Div.*

714. Furnace Charging
12-page brochure on eight models of charging machines for heating and melting furnaces. *Salem-Brosius*

715. Furnace Supplies
8-page catalog on accessories to melting furnaces including linings, silicon-carbide base blocks, burners, blowers, pots and so on. *Lindberg Engineering*

716. Furnaces
44-page Catalog 112, features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. *C. I. Hayes*

717. Furnaces
Bulletin 435 on furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

718. Furnaces
New catalog on standard and special furnaces and ovens to 3000° F. *L & L Mfg. Co.*

719. Furnaces
Brochures on pot furnaces, nitriding, austempering, and martempering and salt baths. *A. F. Holden*

720. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

721. Furnaces
Data on custom-built furnaces. *Industrial Furnace Div., Martin Mfg. Co.*

722. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric Furnace*

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New vacuum furnace bulletin. *National Research Corp.*

724. Furnaces
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12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

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16-page booklet on gamma isotope radiography includes isotopes used, uses, equipment. *Budd Co.*

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24-page booklet on portable gamma ray projectors, using cobalt 60, cesium 137, iridium 192. Operation and construction features. *Metal & Thermit Corp.*

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New bulletins on testing machines for roll testing of spur, worm, spiral and bevel gears. *Geo. Scherr Co.*

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40-page hard facing manual tells what metals can be hard faced, how to select right hard facing material, lists step-by-step procedures and industrial applications. *Haynes Stellite*

733. Hardening Tool Steels
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734. Hardness Conversion Tables
Celluloid card, 2¾ x 4¾ in., gives approximate relationship between Brinell, DPH (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steels. *International Nickel*

735. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

736. Hardness Tester
Bulletin on Brinell tester with test head for deep and offset testing. *King Tester Co.*

737. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

738. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

739. Hardness Tester
Bulletin on Wolpert-Gries Micro-Reflex hardness tester for loads from 10 to 3000 g. *Gries Industries, Inc.*

740. Hardness Testers
20-page book on hardness testing by Rockwell method. *Clark Instrument*

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745. Heat Treating
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754. Heat Treating Fixtures
32-page Catalog G-10 covers heat and corrosion resistant fabricated alloy products. Includes furnace muffles, trays, fixtures, retorts, pit-type furnace equipment, salt bath equipment, pickling and plating equipment. *Rolock, Inc.*

755. Heat Treating Fixtures
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Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

757. Heat Treating Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

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12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

759. Heat Treating Pots
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

760. Heat Treating Supplies
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24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

763. Heliarc Welding
Pocket-sized folder contains current ranges and sizes for electrodes with table on current and number of passes required to weld various metals. *Linde*

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773. High-Temperature Steels
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774. High-Tensile Steel
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8-page bulletin on new electronic induction heaters. Specifications for four models. Special features. *General Electric*

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781. Induction Melting
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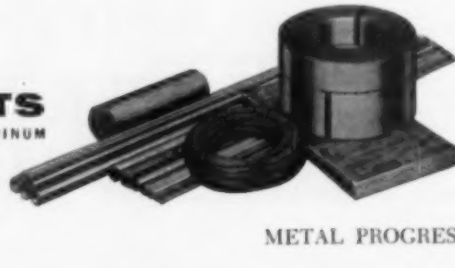

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42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

806. Magnesium Alloys
Loose-leaf folder of data and tables on chemical specifications, properties, extrusion, machining operations. *Brooks and Perkins*

807. Magnesium Extrusions
36-page bulletin gives values of moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

808. Magnesium-Zirconium
10-page reprint on an investigation of zirconium chloride, zirconium fluoride, 40% zirconium-magnesium material for making magnesium zirconium alloys. *Titanium Alloy Mfg. Div.*

809. Malleable Castings
Continuing series of information bulletins covering latest techniques and practices in modern malleable casting. *Malleable Founders' Society*

810. Metal Cutting
64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

811. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

812. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

813. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

814. Microscopes
New brochure SB 56 on Cycloptic stereoscopic microscope. *American Optical*

815. Molybdenum
24-page booklet gives physical and chemical property data on molybdenum powders, wire, alloys. *Sylvania Electric*

816. Mo-Fe Castings
Bulletins 1 and 2 on molybdenum iron castings give advantages of molybdenum in these castings. *Climax Molybdenum*

817. Nickel Alloy
12-page booklet on Hastelloy Alloy R-235, vacuum-melted wrought alloy containing aluminum and titanium. *Haynes Stellite Co.*

818. Nickel Alloys
Wall chart gives engineering properties of nickel alloy wire, rod and strip. Includes Monel, Inconel, Incoloy and nickel-clad copper. *Alloy Metal Wire Co.*

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8-page bulletin with 28 charts on composition, heat treatment, transformation

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Rokide spray coatings help solve many high temperature and wear problems

WITH the rapid increase in modern high temperature applications there has been a corresponding increase in demands for resistant materials. Norton ROKIDE spray coatings are meeting such demands with great success. These hard, adherent crystalline refractory oxides offer many important advantages. For example:

They are both thermally and electrically insulating . . . Their hardness, chemical inertness and stability in combustion temperatures provide high resistance to excessive heat, abrasion, erosion and corrosion. Their high melting points and low thermal conductivities reduce the temperatures of the underlying materials and permit higher operating temperatures.

ROKIDE Coatings vs. Stainless Steel

Analyses of Norton ROKIDE spray coatings and of stainless steel reveal interesting comparisons. While less dense than the bare steel, the ROKIDE coatings are very much harder, have considerably higher melting points and are very much lower in thermal conductivity and thermal expansion.

Proof

There are three Norton ROKIDE coatings: ROKIDE "A" aluminum oxide, ROKIDE "ZS" zirconium silicate and ROKIDE "Z" stabilized zirconia. Thoroughly proved in such critical applications as reaction motors, as well as in AEC projects, the value of these coatings to a broad range of more conventional applications is obvious.

Applications

The versatility and adaptability of ROKIDE coatings are evident in the following list of applications, actual and suggested:

Baffle plates . . . bearing surfaces . . . mechanical seals . . . feed rolls . . . metal treads . . . thermal barriers . . . reflection coatings . . . coatings for exhaust ports, duct linings, ladles and crucibles . . . insulation for copper bus-bars, circuit breaker components, thermocouple wires and tubes, large and small electronic equipment . . . protection for nozzles, valve plugs, piston heads, pump shafts, gas turbine parts, etc.

Although ROKIDE coatings are most commonly applied to metals they are effective on other materials, such as ceramics and certain plastics. Thicknesses of the coatings generally range from .005" to .05".

Other Norton Electric Furnace Materials

are products made of CRYSTOLON* silicon carbide (including ROKIDE "C" coating for graphite parts and CRYSTOLON "N" monolithic shapes), ALUNDUM* fused alumina, MAGNORITE* magnesium oxide, NORBIDE* boron carbide and Fused Stabilized Zirconia. These high-melting materials are also the basic ingredients of the famous Norton R's — refractories *engineered and prescribed* for the widest range of uses.

For more detailed information on ROKIDE coatings, use the coupon.

NORTON COMPANY
New Products Division
Worcester 6, Massachusetts

ROKIDE Spray Coatings are applied in a molten state by means of a metalizing type spray gun. The oxide is fed into the gun in rod form at a carefully controlled rate. The coatings can be applied to parts of any size and to all shapes accessible to the spray gun equipment.

[ROKIDE Spraying Equipment Manufactured by Metallizing Company of America, Chicago 32, Illinois.]

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Cleveland Auditorium

characteristics and mechanical properties of the standard nickel-chromium steels. *International Nickel*

820. Nickel Plating
10-page paper on nickel plating process describes plating solution and operating conditions, make-up and control of solutions, analysis and properties. *Sel-Rex Precious Metals*

821. Nickel Plating
20-page instruction manual on bright nickel plating by the nickel-lume process. Bath preparation, converting existing baths, solution maintenance and purification. *Hanson-Van Winkle-Munning*

822. Nickel Tubing
New 20-page catalog gives properties and compositions of 13 analyses of nickel and nickel alloy tubing. Selection guide. *Superior Tube*

823. Nitriding
Data on process for nitriding stainless steel. *Standard Steel Treating*

824. Nondestructive Inspection
8-page bulletin on use of ultrasonic Reflectoscope describes principles of ultrasonic inspection and its uses. *Sperry Products*

825. Nondestructive Testing
Data on new nondestructive thickness tester. *Unit Process Assemblies*

826. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

827. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

828. Nonferrous Forgings
34-page booklet on brass, bronze and aluminum forgings. How they are made, composition of alloys, tolerances. *Mueller Brass*

829. Nonflammable Rust Preventive
Bulletin on rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

830. Oil Quenching
Catalog V-1146 on self-contained oil cooling equipment. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

831. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

832. Openhearths
Brochure on modern openhearth design and construction. *Loftus*

833. Ovens
New 16-page catalog on techniques used in process heating systems. Methods combining radiation and convection. *Jensen Specialties*

834. Oxygen Analysis
4-page bulletin on new oxygen sampling and recording equipment for openhearth waste gases. *Leeds & Northrup*

835. Phosphate Coating
12-page "Phosphate Coating Chemicals and Processes" gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

836. Pickling
80-page book, "Efficient Pickling", covers all variables of process. Many charts and tables. *American Chemical Paint*

Pangborn Rotoblast® Cuts Cleaning Costs $250 a Day for General Foundries!

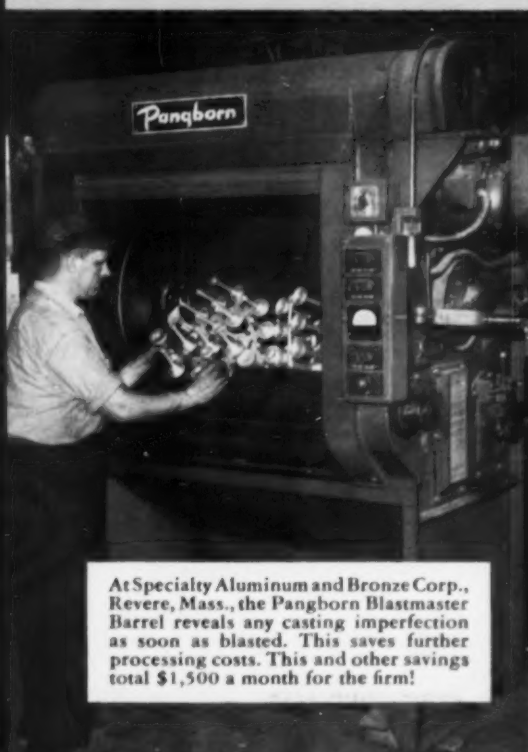
General Foundries, Milwaukee, Wis., replaced its old cleaning equipment with a Pangborn Rotoblast Table-Room and a Blastmaster Barrel, reducing labor costs and eliminating casting breakage to the tune of $250 a day!

Some foundrymen tell us they're most impressed with Pangborn Rotoblast's speed of cleaning, its high production rate. Others praise the quality of its work . . . the manpower reduction due to its automatic operation. But whatever the reasons—cleaning quality, speed, lower labor and maintenance costs, no abrasive loss—they all add up to the fact that Pangborn Rotoblast gives you *lower cost per ton of castings cleaned.* And, in the final analysis, this figure determines the efficiency of your blast cleaning operation.

Investigate Pangborn Rotoblast and discover which machine can best streamline your operating costs! Write for Bulletin 227 to PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Maryland. *Manufacturers of Blast Cleaning and Dust Control Equipment.*

Visit our Booths 8 to 12, Iron & Steel Exposition, CLEVELAND, SEPTEMBER 25 to 28

And $1,500 a month for Specialty Aluminum and Bronze!



At Specialty Aluminum and Bronze Corp., Revere, Mass., the Pangborn Blastmaster Barrel reveals any casting imperfection as soon as blasted. This saves further processing costs. This and other savings total $1,500 a month for the firm!

Pangborn

BLAST CLEANS CHEAPER

Rotoblast Blastmaster® & Continuous-Flo Barrel | Rotoblast® Tables & Table-Rooms | Special Blast Rooms & Cabinets | Pangborn Dust Control Equipment

Distributors for Malleabrasive and Tru-Steel Abrasives

837. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

838. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

839. Post-Weld Heat Treatment
8-page bulletin TR-543 demonstrates the need for post-weld heat treatment of air hardening alloys. *Babcock & Wilcox*

840. Powder Metallurgy
4-page folder presents extensive powder metallurgy bibliography for 1954 and 1955. *Harper Electric Furnace Corp.*

841. Powdered Metals
Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. *New Jersey Zinc*

842. Powdered Metals
Bulletin 800-B on pre-alloyed iron powders with varied chromium-nickel contents. *Metal Hydrides*

843. Powdered Metals
Booklet tells how things are made of powdered metals, applications and future possibilities. *Stokes*

844. Precision Casting
12-page book tells when to use precision castings, tolerances, how castings are made. *Alexander Saunders*

845. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

846. Precision Castings
12-page booklet gives data on casting design, size of castings, quality control, for precision castings of brass, bronze and aluminum alloys. *Atlantic Casting and Engineering*

847. Pressure Switch
Specification S1011-1 on new industrial gas pressure switch for use on multiple burner gas installations. Chief features. *Minneapolis-Honeywell Regulator*

848. Processing Equipment
Folder on rolling mills, slitting lines and accessory equipment. *Stanat*

849. Pyrometers
12-page Bulletin 713 on indicating and controlling pyrometers. Functional diagrams of installations. *General Electric*

850. Quenching Oil
Technical bulletin on quenching oil and accelerators to provide deeper hardening. *Park Chemical*

851. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

852. Radiant Heat
Bulletin HD-740R describes and illustrates construction of radiant heat elements and shows how they are installed in furnaces. *Hevi Duty*

853. Radiography
16-page bulletin on materials and accessories for radiography. Density curves for four types of films. *X-Ray Div., Eastman Kodak*

854. Radiography
26-page brochure on very high voltage equipment for radiography and how it is used. *High Voltage Engineering*

855. Recirculating Furnace
Bulletin on continuous-type recirculating furnace shows design of furnace, its operation and advantages. *Industrial Heating Equipment*

856. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

857. Refractories
24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. *Norton*

858. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3000° F. *Morganite*

859. Resistance Welding
56-page catalog of resistance welding products, accessories and materials. Selection of alloys and electrode materials. *Weldaloy Products Co.*

860. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

861. Roll Formed Shapes
24-page Bulletin 1053 on designing, forming and producing shapes from ferrous and nonferrous metals. *Roll Formed Products Co.*

862. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

863. Salt Baths
32-page bulletin on salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton*

864. Salt Baths
Bulletin 800 on air-driven molten salt pump. Advantages of pump. Performance data. *Ajax Electric*

865. Salt Baths
Reprints 161 and 162 on new advances in hot salt quenching and salt bath quenching of gears. *Ajax Electric*

866. Saw Blades
Selector for hand or power blades tells which blade to use for various alloys and shapes. *Henry Disston*

867. Saws
Catalog C-53 describes 35 models of metalcutting saws. *Armstrong-Blum*

868. Silver Brazing
Series of eight technical bulletins on silver brazing. Joint strength, design, stress analysis, heat treatment, fluxes. *Handy & Harman*

869. Silver Plating
8-page paper on bright silver plating process covers solution maintenance and operating conditions. *Sel-Rex Precious Metals*

870. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

871. Sodium
40-page booklet on handling metallic sodium gives typical sodium using processes, equipment installation, recommendations for pumping and instrumentation. *U.S. Industrial Chemicals*

872. Solvent Cleaning
16-page booklet on how to use solvent detergents for removing carbon, grease, dirt, paint. *Oakite Products*

873. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel*

874. Specimen
Article on practical system for prepar-
(*Continued on p. 48-A*)

(Continued from page 47)
ing metallographic specimens, in July issue of "Metal Digest". *Buehler*

875. Spectrograph
8-page booklet on optical emission, direct reading spectrographs for production control and research. *Applied Research Labs.*

876. Spectrograph
24-page booklet on Echelle spectrographs. Advantages. Type of work produced. *Bausch & Lomb*

877. Spectrograph
New 8-page catalog on Spec-Lab. Performance and applications of three models. *Jarrell-Ash*

878. Spectrometer
8-page Bulletin 44 on direct reading spectrometers. Operation and construction. *Baird Associates*

879. Speed Recorders
Data Sheet ND46-27(1) on Speedomax G recorders for measurement of rotational and linear speeds and about the tachometer generators used with them. *Leeds & Northrup*

880. Spring Steels
Spring steel catalog offers 785 sizes of hardened and tempered spring steels, and 133 cold rolled and bright annealed sizes in stock. *Sandvik Steel*

881. Stainless Castings
11 reference sheets for major stainless casting alloys give compositions, properties, resistance to corrosive solutions, machinability, heat treatment, weldability. *Cooper Alloy*

882. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

883. Stainless Steel
44-page book gives detailed information on use of stainless steel in the chemical industries. *Crucible Steel*

884. Stainless Steel
Data sheet on Type 301 gives physical properties, corrosion and oxidation resistance, mechanical properties. *Allegheny Ludlum*

885. Stainless Steel
32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. *International Nickel*

886. Steel
Bulletins on hot work steel and Type 420 stainless give forging, annealing and hardening characteristics. *Firth Sterling*

887. Steel
256-page handbook lists sizes, weights, lengths, steels available, shapes. Data on mechanical properties, standard steel compositions, hardness numbers conversions. *Ryerson*

888. Steel 52100
Data sheet on high-purity 52100 steel, made by vacuum melting. *Vacuum Metals*

889. Steel Treating
Bulletin on flame hardening, induction hardening, carbonitriding, nitriding, liquid carburizing, Chapmanizing. *Lakeside Steel Improvement*

890. Steel Tubing
48-page Handbook F-3 on fabricating and forging steel tubing. Bending, shaping, cutting and joining operations described. *Ohio Seamless Tube*

891. Steelmaking
Beautifully illustrated brochure on steelmaking, annealing, hot rolling, finishing. *Rotary Electric Steel*

892. Strain Gages
8-page article on performance of SR-4 high temperature strain gages and how to apply them in "Testing Topics". *Baldwin-Lima-Hamilton Corp.*

893. Sub-Zero Equipment
12-page catalog of chilling machines and temperature testing units. *Cincinnati Sub-Zero Products*

894. Swaging Machines
16-page catalog on complete line of swaging equipment contains data on rotary swaging process and its applications. *Fenn Mfg. Co.*

895. Temperature Conversion
16-page temperature conversion booklet and electromotive force of thermocouple alloys in absolute millivolts. *Wheelco*

896. Temperature Measurement
8-page catalog 175 on optical, micro-optical, radiation, immersion and surface pyrometers. *Pyrometer Instrument Co.*

897. Test Equipment
Catalog R-36A on complete line of testing equipment, including all industrial electronic and electrical equipment. *Weston Electrical Instrument*

898. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

899. Testing Equipment
Details and specifications of complete line of base plates in new illustrated booklet. *Lake Shore, Inc.*

900. Testing Machines
28-page catalog on screw power universal testing machines and accessories. Construction, specifications. *Riehle*

901. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

902. Thermocouple Alloys
20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

903. Thermocouple Restorer
New catalog R-27 on device for renewing proper electrical conductivity through thermocouples and thermocouple circuits. *Peerless Electric Co.*

904. Thermocouple Wire
Bulletin on thermocouple wire and thermocouple extension wire lists sizes, metals, insulations. *Claud S. Gordon*

905. Thermocouples
New 14-page bulletin No. 5 on miniature protected thermocouples. Calibrations and temperature ranges available, immersion lengths and other data. *Thermo Electric*

906. Thermocouples
32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument Corp.*

907. Tin News
Interesting monthly report covers important current developments in the production, marketing and use of tin. *Malayan Tin Bureau*

908. Titanium
8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with stainless and aluminum in various mediums. *Mallory Sharon*

909. Titanium and Zirconium
16-page bulletin, "The Hydrimet Process", on titanium and zirconium metals and hydrides, and other metallurgical hydrides. *Metal Hydrides*

910. Tool and Die Steels
26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem Steel*

911. Tool Steel
Wall chart showing more than 300

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varieties of tool steel with trade name of manufacturers. *Vulcan Crucible Steel*

912. Tool Steel
Data sheets on high speed, hot work, air, oil and water hardening tool steels, alloy steels, machinery steels, stainless steels, welding rods. *Crucible Steel*

913. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

914. Tool Steels
Data on air-hardening hot work die steel for forging. *Ziv Steel & Wire Co.*

915. Tubes
Bulletin TB-412 on electric-resistance-welded carbon steel tubes for heat exchangers and condensers. *Babcock & Wilcox*

916. Tubing
Data Memorandum No. 4 on large diameter thinwall tubing in seamless and Weldrawn grades. Applications. *Superior Tube*

917. Tubing
52-page "Handbook of Seamless Steel Tubing". 26 pages of data. *Timken*

918. Tubing
12-page catalog on cold drawn, mechanical, capillary, nickel and nickel alloy tubing. *J. Bishop & Co. Platinum Works.*

919. Tukon Tester
12-page bulletin DH-114 on Tukon micro and macro hardness testers. *Wilson Mech. Inst.*

920. Tumbling
8-page booklet on precision tumbling, a controlled-motion honing process for parts which could not previously be finished by tumbling. *BMT Mfg. Corp.*

921. Tungsten Alloy
Data on properties and uses of 95% tungsten alloy, balance nickel and copper. *Firth Sterling*

922. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

923. Ultrasonic Cleaning
Folder on principles and methods of metal cleaning by application of ultrasonic energy. *Detrex*

924. Ultrasonic Inspection
Ultrasonic Inspection Newsletter, No. 2, contains article on immersion inspection of wing spars for jet fighters. *Sperry Products*

925. Ultrasonic Testing
Data folder describes instruments using ultrasonics for various tests—immerscope, "B" scan and flaw recorder. *Curtiss-Wright*

926. Vacuum Alloys
Folder on vacuum melted cobalt, ferrous and nickel base alloys. Quality control. *Cannon-Muskegon Corp.*

599. Product File
More than 30 new product developments, more than 700 booklets, bulletins and engineering data sheets are presented in a 16-page file reference in *Application and Equipment News*. Reprinting the product and literature items that have appeared in *Metal Progress* during the third quarter of 1956, this handy summary of what's new in metals, design applications, processing, fabrication and equipment may be used throughout the year.

927. Vacuum Melting
8-page bulletin on production and testing equipment for vacuum melting. Advantage. *Utica Metals Div., Utica Drop Forge & Tool*

928. Vacuum Melting
Data on new laboratory vacuum melting furnace. *High Vacuum Equipment*

929. Vacuum Metals
21-page report on vacuum melted metals discusses equipment, properties of metals and their applications. *Ajax Electrothermic Corp.*

930. Vacuum Pumps
New 52-page catalog No. 425 on high vacuum pumps contains formulas and tabular data. *Kinney Mfg.*

931. Vacuum Systems
Booklet on vacuum drying, impregnation, metallizing, pumping systems. *Stokes*

932. Vanadium
"Vancoram Review", Spring 1956, tells story of discovery of vanadium ore in Peru. *Vanadium Corp.*

933. Welding
52-page catalog on gases, welding and cutting equipment and accessories for job shops, maintenance departments and other users of light gas and arc equipment. *Air Reduction Sales*

934. Welding Copper
24-page booklet on oxyacetylene, carbon-arc and metal-arc welding techniques for copper and copper alloys. *Revere*

935. Welding Electrodes
84-page pocket-size booklet describes characteristics, coating, sizes of various electrodes and compares them with standard designations and other electrode brand names. *Harnischfeger*

936. Welding Equipment
Folder on equipment for welding and cutting by the acetylene process. Regulators, torches and other equipment. *Dockson Corp.*

937. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

938. Welding Magnesium
Various welding processes for magnesium, stress relief and recommended procedures. *Brooks & Perkins*

939. Welding Rods
Folder on eight welding rods for steel, cast iron, brass and bronze. Techniques for gas welding. *Metal & Thermit*

940. Wire Cloth
Bulletin 113 on wire cloth in various alloys, in bulk or specially fabricated parts. *Cambridge Wire Cloth*

941. Wire Straightening
20-page brochure on wire straightening and cutting machines, wire reels, chamfering and deburring machines. New air clutch described. *Lewis Machine Co.*

942. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

943. X-Ray Equipment
12-page booklet on 250-kv constant potential X-ray equipment for internal inspection. Advantages, design features. *Westinghouse Electric*

944. X-Ray Supplies
Bulletin on X-ray films and chemicals for radiography. *Ansco*

945. Zinc and Cadmium Plate
Technical data sheets on use of Luster-on salts for zinc and cadmium plating. *Chemical Corp.*

SEPTEMBER, 1956

571	598	625	652	679	706	733	760	787	814	841	868	895	922
572	599	626	653	680	707	734	761	788	815	842	869	896	923
573	600	627	654	681	708	735	762	789	816	843	870	897	924
574	601	628	655	682	709	736	763	790	817	844	871	898	925
575	602	629	656	683	710	737	764	791	818	845	872	899	926
576	603	630	657	684	711	738	765	792	819	846	873	900	927
577	604	631	658	685	712	739	766	793	820	847	874	901	928
578	605	632	659	686	713	740	767	794	821	848	875	902	929
579	606	633	660	687	714	741	768	795	822	849	876	903	930
580	607	634	661	688	715	742	769	796	823	850	877	904	931
581	608	635	662	689	716	743	770	797	824	851	878	905	932
582	609	636	663	690	717	744	771	798	825	852	879	906	933
583	610	637	664	691	718	745	772	799	826	853	880	907	934
584	611	638	665	692	719	746	773	800	827	854	881	908	935
585	612	639	666	693	720	747	774	801	828	855	882	909	936
586	613	640	667	694	721	748	775	802	829	856	883	910	937
587	614	641	668	695	722	749	776	803	830	857	884	911	938
588	615	642	669	696	723	750	777	804	831	858	885	912	939
589	616	643	670	697	724	751	778	805	832	859	886	913	940
590	617	644	671	698	725	752	779	806	833	860	887	914	941
591	618	645	672	699	726	753	780	807	834	861	888	915	942
592	619	646	673	700	727	754	781	808	835	862	889	916	943
593	620	647	674	701	728	755	782	809	836	863	890	917	944
594	621	648	675	702	729	756	783	810	837	864	891	918	945
595	622	649	676	703	730	757	784	811	838	865	892	919	
596	623	650	677	704	731	758	785	812	839	866	893	920	
597	624	651	678	705	732	759	786	813	840	867	894	921	

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Please have literature circled at the left sent to me.

Name ______________________

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Company ______________________

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Postcards must be mailed prior to Dec. 1, 1956. Students should write direct to manufacturers.

LABORATORY REPORT
from
ALLOY METAL DIVISION ALTER CO
NICKEL CHROME – NICKEL COPPER – FERRO NICKEL – NI
1701 ROCKINGHAM ROAD DAVENPORT, IOW

Shipped June 2, 19

To [redacted] Steel Company
[redacted] Pennsylvania

Gentlemen:

Sample No. See Below Representing 50,000# Net Ni-Cr All

has been carefully tested and we report our analysis as follows:

Heat#	Gross	Tare	Net	Ni	Cr	C	Si*	Mn*	M
B-1-10	1338	42	1296	60.49	14.98	.27	.57	.65	
B-1-11	1282	46	1236	60.38	14.87	.25	.51	.60	
B-1-12	1364	44	1320	60.75	14.83	.28	.58	.63	
B-1-13	1286	46	1240	60.24	14.95	.24	.55	.68	
B-1-14	1298	43	1255	60.94	14.97	.23	.52	.59	
B-1-15	1358	42	1316	60.87	14.82	.19	.56	.60	
B-1-16	1308	40	1268	60.91	14.88	.24	.57	.61	
B-1-17	1232	46	1186	60.73	15.01	.27	.51	.63	
B-1-18	1320	46	1274	60.41	15.10	.20	.55	.58	
B-1-19	1296	44	1252	60.27	15.03	.23	.53	.57	
B-1-20	1332	48	1284	60.95	14.90	.24	.51	.55	
B-1-21	1290	44	1246	60.34	14.88	.28	.50	.59	
B-1-22	1350	46	1304	60.41	14.85	.30	.56	.58	
B-1-23	1298	43	1255	60.07	14.95	.27	.55	.56	
B-1-24	1282	46	1236	60.31	15.15	.29	.51	.57	
B-1-25	1308	40	1268	60.86	15.21	.24	.50	.60	
B-1-26	1364	44	1320	59.97	14.78	.25	.56	.61	
B-1-27	1338	42	1296	60.41	14.88	.23	.54	.59	
B-1-28	1296	44	1252	60.32	14.90	.26	.52	.58	
B-1-29	1332	40	1292	60.27	14.88	.20	.54	.6	
B-1-30	1350	45	1305	60.34	14.95	.20	.58	.5	
B-1-31	1286	40	1246	60.49	15.21	.19	.50	.5	
B-1-32	1298	45	1253	60.24	14.88	.23	.51	.	

(Continued on Page 2)

* Spectrographic Analysis

Analysed by

Checked by

Signed

We certify this is a true and accurate analysis.
ALTER COMPANY

STATE OF IOWA
COUNTY
Subscribed and sworn to ... day of Aug 1956

My commission expires July 4 - 1957

Our business is staked on it

. . . will you try one heat on it?

THIS IS OUR LABORATORY REPORT on one customer's order for Alloymet nickel base pig and shot* for stainless steel production.

It gives a complete analysis of *each heat* included in the total order. A notarized report such as this travels with every order of Alloymet alloys.

These alloys of certified analysis are available at approximately 5% over the cost of nickel alloy scrap.

Contact us now — discover why use of these alloying agents more than compensates for their slight premium in cost.

**Alloymet available in a complete range of nickel chrome, nickel iron and nickel copper analyses.*

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1701 ROCKINGHAM ROAD
DAVENPORT, IOWA

World's largest producer of secondary nickel alloys of certified analysis


NEW! FAST! LONG LASTING!...
A new high-speed quenching oil with an extra-long service life

WAVERLY design

PANTHEON design

METALS AND ALLOYS REVIEW

by FRANK M. LEVY
Vice-President and Director of Research

Last week one of our sales engineers was at the home office and we were talking about one of his customers in the East who manufactures milling machines which are being used for milling aircraft spars. We are supplying gibs, slide bars and wear strips to this company made of our "600" series bearing metal in rectangular rod form. The material formerly used was aluminum bronze* cast bars which they could only obtain in 36" lengths. Their engineering department estimates that costs have been reduced 50% on this component. Machining time has been reduced and impregnation of porous castings has been eliminated.

Our sales representative was curious about my experience with "600" in other applications such as this. Oddly enough, our own plant has been a pretty good proving ground. In our extrusion department, for example, we have gotten exceptionally good service from slides made of "600" and used on the die heads which are subject to pressure and extremely rough usage.

Bob Irwin of our forging department reports that the "600" strips he has used for lining the ways of our big forging presses have proved far superior to the bronzes which were original equipment. The bronze strips squashed out after protracted running. More important, the "600" strips last 10 times longer before replacement is necessary.

In our copper tube fabricating department we have a lot of automatic equipment for the production of formed tube shapes like tees and ells used in the plumbing industry. On one of the tube benders, there was no provision made for replacing worn forming slides. Our Maintenance Department reworked the machine using "600" strips as replaceable forming slide inserts. The bender is now a far more efficient machine. Because of the long life of "600", downtime on this machine has been practically eliminated.

While we were talking about these uses in our own plant, it brought to mind some other instances where the exceptionally good wearing properties of "600" have been established. A Cincinnati lathe manufacturer uses "600" in the form of counter sunk hexheaded screws on wearing strips used on lathe carriages. When the strip wears to the retaining screw the ways will not be scratched.

According to their own records, all other materials which they had tested proved unsatisfactory for the job. Another maker of precision lathes and milling machines found that after a year of exhaustive tests, the "600" metal that was used as nuts on compound slide screws outlasted competitive metals at an approximate ratio of 3 to 1 at an estimated saving of 30%.

Sliding surfaces on all kinds of machinery have different wear characteristics, as you have undoubtedly found. If you have any problems involving gibs, slide bars or wear strips that are proving troublesome, why not drop me a line or send a part print and we'll be glad to study it and make the proper recommendations.

*We manufacture 4 grades of wrought aluminum bronze.

• WRITE TODAY FOR THE ENGINEERING MANUAL YOU NEED

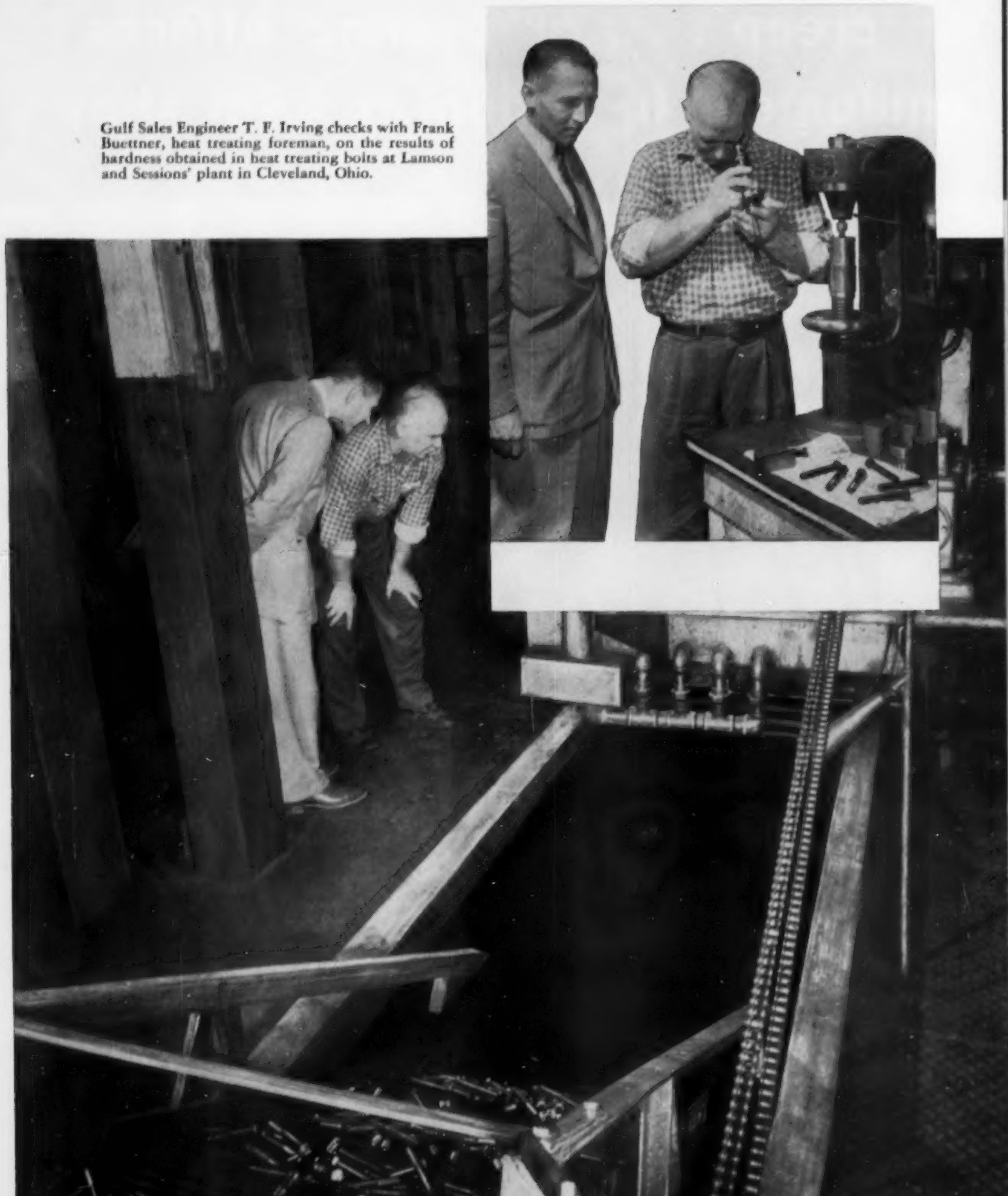
- [ ] Mueller Brass Co. Forgings Engineering Manual H-58565
- [ ] Tuf Stuf Aluminum Bronze Alloys Engineering Manual H-58563
- [ ] 600 Series Bearing Alloys Engineering Manual FM-3000
- [ ] Copper Base Alloys in Rod Form Engineering Manual FM-3010

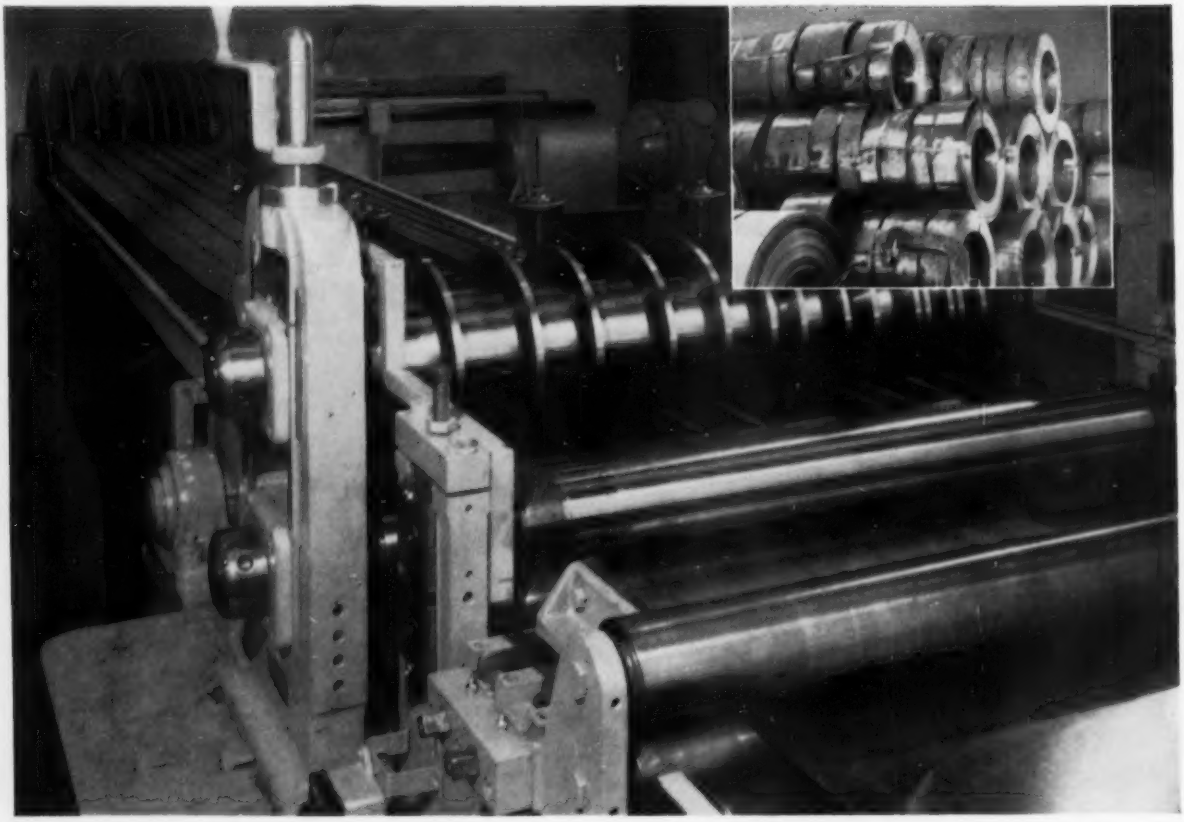
MUELLER BRASS CO.

PORT HURON 20, MICHIGAN

185

Gulf Sales Engineer T. F. Irving checks with Frank Buettner, heat treating foreman, on the results of hardness obtained in heat treating bolts at Lamson and Sessions' plant in Cleveland, Ohio.





...these things and others, too, a Yoder Slitter can do for you...

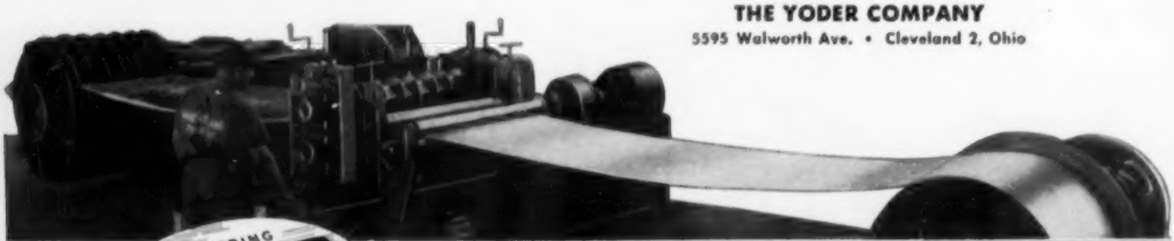
By doing your own slitting, you may easily save $12,000 or more per year in slitting cost alone, on requirements as low as 100 tons per month.

But don't make the mistake of thinking this is the only saving or advantage enjoyed. Many owners realize equally important savings by being able to buy standard width coils competitively, from more numerous sources of supply—wherever they can get the best price and quality. Much quicker deliveries are also obtainable in this way.

Inventory requirements, too, are greatly reduced and production planning simplified because, from a relatively small stock of mill-width coils or sheets, you can meet expected and unexpected needs for slit strands in a few hours.

Send for the Yoder Slitter Book—a comprehensive text on the mechanics and economics of slitters and slitting line operation, with time studies, cost analyses and other valuable data. It's yours for the asking.

THE YODER COMPANY
5595 Walworth Ave. • Cleveland 2, Ohio



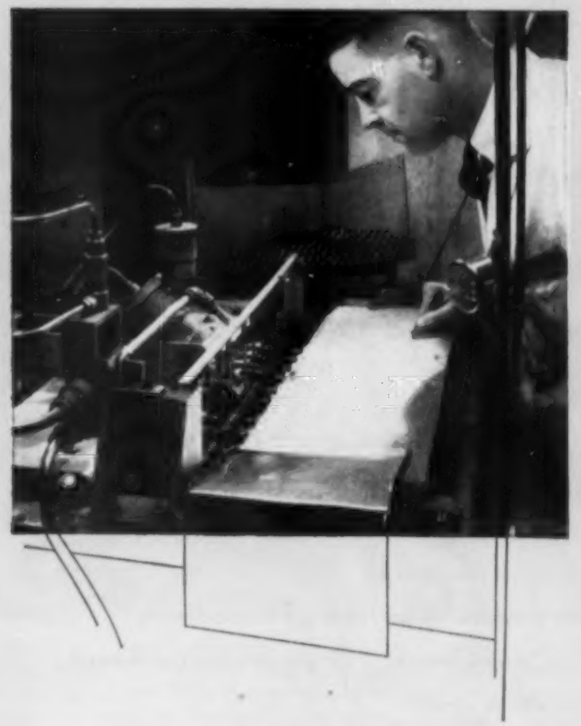
ENGINEERING YODER MANUFACTURING

ROTARY SLITTING LINES

COLD ROLL FORMING MACHINES

ELECTRIC-WELD PIPE AND TUBE MILLS

'**dag**' dispersions... *a touch does so much!*



Tool-life increased 60 times

In an unusual multiple-spindle drilling operation, a machine-tool firm found that straight cutting-oil did not give satisfactory performance. Drills constantly had to be resharpened after sinking about 50 holes.

However, when a 1:300 dilution of a **'dag'** dispersion of colloidal molybdenum disulfide in oil was tried, tool life before resharpening was extended to 3,000 holes!

This result is typical of the production improvements which can be realized through the use of this outstanding new high-pressure lubricant. Whatever your machining operation, it is likely that molybdenum disulfide can help. And Acheson Colloids' service engineers can give you the benefit of their experience in its application. Why not get in touch with your nearby Acheson representative? Meanwhile, write for your free copy of Bulletin No. 424.

ACHESON COLLOIDS COMPANY

PORT HURON, MICHIGAN

... also Acheson Colloids Ltd., London, England

ACHESON COLLOIDAL DISPERSIONS:
Graphite • Molybdenum Disulfide • Zinc Oxide
Mica and other solids

'dag' is a registered trademark of Acheson Industries, Inc.

100th Anniversary

Acheson Colloids Company, Dept. C-9
Port Huron, Michigan

Yes, I want to get your free catalog on 'dag' dispersions for use in Industrial Lubricants.

Name ______________________

Title ______________________

Company ______________________

Address ______________________

City ______________ Zone ____ State ______

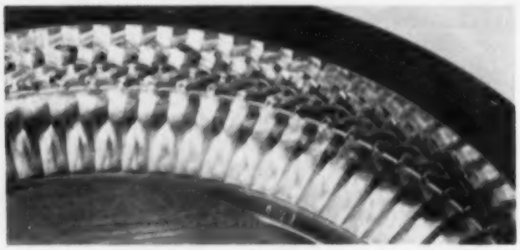
STEEL MACHINING CASE STUDY

How $30 worth of steel plate took the risk out of a $4000 machining job!

There's a quick, sure way to select exactly the right steel—whatever your particular application. Draw on the wide experience of Ryerson specialists who are working with hundreds of other steel users on similar problems every day. The right steel can make a big difference—can mean a better product, lower production costs—as the following case study illustrates.

THE PROBLEM—Central Mold & Machine Company of Akron contracted to make a chrome-plated mold for producing an exact duplicate, in miniature, of Firestone's new Supreme tubeless tire.

Only a very small piece of plate steel was needed for the job—but the steel had to be extraordinarily clean and sound. Hundreds of hours of machining time were to be "invested" in it and some of the tiny lands that formed the unusually intricate tread design were only .015 of an inch thick!



A close up of the mold for the 6" tire showing intricate machining with lands only .015" thick.

SOLUTION—Working with a Ryerson representative, Central Mold & Machine selected New E-Z-Cut plate for the job. Because this Ryerson leaded plate steel is remarkably clean and free of excessive stringers, even the finest lands of the mold were sharp and true. Because New E-Z-Cut machines as much as 30% faster than mild steel plate, the difficult machining job was completed in minimum time. And because New E-Z-Cut machines to a high finish and polishes readily, the mold was very satisfactorily prepared for plating, at low cost.

If a better quality free-machining plate had been available at any price it would have been used here because, at almost any price, the cost of the steel would be only a tiny fraction of the cost of the finished mold. New E-Z-Cut (approximately $30.00 worth) was used because it took the steel risk out of a $4000 machining job.

Whatever your steel problem, it will pay you to check with Ryerson specialists and draw on Ryerson stocks of highest quality, special purpose steels.

NEW E-Z-CUT PLATE VS. MILD STEEL
A Machining Demonstration
Booth 405—National Metal Exposition

The remarkable machinability of our New E-Z-Cut leaded plate steel will be demonstrated at the October National Metal Exposition in Cleveland. Don't miss it!

Flame cutting also demonstrated—Watch the actual burning of intricate steel shapes with electric eye equipment.

RYERSON STEEL

In stock: Carbon, alloy and stainless steel . . . bars, structurals, plates, sheets, tubing, reinforcing bars, machinery & tools, etc.

JOSEPH T. RYERSON & SON, INC. PLANTS AT: NEW YORK • BOSTON • WALLINGFORD, CONN. • PHILADELPHIA • CHARLOTTE, N. C. • CINCINNATI CLEVELAND • DETROIT • PITTSBURGH • BUFFALO • CHICAGO • MILWAUKEE • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • SPOKANE • SEATTLE

Metal Progress

Volume 70, No. 3 **September, 1956**

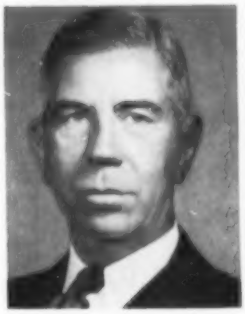
The next 32 pages of this issue of Metal Progress are occupied by an outline – the barest outline – of the program of the 38th National Metal Congress and a listing of the 470 exhibitors in the National Metal Exposition. The Exposition has been limited only by the capacity of Cleveland's Public Auditorium and its seven exhibition areas. The Congress of American Society for Metals and the cooperating societies gives such a variety of technical fare that we have presented the meetings morning by morning and afternoon by afternoon, so the metals engineer may easily choose the topic of most interest to him at a given time.

The early birds will have Saturday and Sunday for a high-level discussion of creep and recovery culminating in a lecture by E. N. daC. Andrade, the leading British authority. Monday morning the American Welding Society will listen to the Adams Lecture. On Wednesday morning the 's Campbell Memorial Lecture will be given by Charles S. Barrett on "Metallurgy at Low Temperatures"; and on Wednesday afternoon N. L. Mochel will deliver the Society for Nondestructive Testing's Mehl Honor Lecture.

An entirely new event, the "Awards Luncheon", will be held on Tuesday. After presentations of several awards, each recognizing some notable contributions to the metal industry, Charles M. White, chairman of the board of Republic Steel Corp. will talk briefly on our industry's engineering manpower problems and opportunities.

The Annual Banquet on Thursday evening

John R. Dunning
Dean of Engineering
Columbia University
Principal Speaker at
Banquet



Charles M. White
Board Chairman
Republic Steel Corp.
Principal Speaker at
Awards Luncheon

will have as its principal speaker John R. Dunning, dean of engineering at Columbia University, whose knowledge of such things as atomic fission is matched only by his wit and urbanity.

Industrial Heating Equipment Assoc. will hold another of its notable conferences – this one on Tuesday morning, and the topic is Controlled Atmospheres and Their Control. Thursday will see an entirely new type of meeting, an Discussion Forum on Stamping Dies – no speakers, no papers, no preparation. Imagine! That same day at the Carter Hotel the is cooperating with the Atomic Energy Commission in a comprehensive discussion of "The Metal Thorium".

These are only some of the highlights of the Congress.

Friday the National Metal Congress will be host to all junior members of the attending colleges within bus-riding distance. At noon will be the Distinguished Service Luncheon where 25-year members will sit elbow to elbow with the youngsters who will carry on the metal industry in the future.

All this week, afternoon and evening, the National Metal Exposition will have its doors open to members of the cooperating societies and their guests. If past records from the registration desk can be relied upon, more than 50,000 such men will pass through the turnstiles.

Come to Cleveland in October and get some new ideas. Bring as many of your associates as necessary to attend all the interesting events. One good idea picked up during the week will repay the cost many times over!

National Metal Congress

Cleveland, Oct. 6 through 12, 1956

American Society for Metals

Headquarters, Statler Hotel

Technical sessions, Monday through Friday morning
Seminar on Creep and Recovery, Saturday and Sunday
Educational Course on Residual Elements, Monday and Tuesday
Educational Course on Fatigue, Thursday
Discussion Forum on Dies, Thursday
Joint Conference with A.E.C. on Thorium, Thursday

American Institute of Mining and Metallurgical Engineers, Institute of Metals Division

Headquarters, Carter Hotel

Technical sessions, Monday through Wednesday
Symposium on Titanium, Tuesday

American Welding Society

Headquarters, Cleveland Hotel

Technical sessions, Monday afternoon through Friday morning
Educational Lectures, Tuesday and Wednesday afternoon
Plant tours, Wednesday and Thursday morning

Society for Nondestructive Testing

Headquarters, Hollenden Hotel

Educational sessions, Monday
Technical sessions, Tuesday through Thursday

Industrial Heating Equipment Association

(Jointly with ASM)

Technical sessions, Tuesday

Special Libraries Association, Metals Division

Headquarters, Manger Hotel

Technical sessions, Thursday
Field trips, Wednesday and Friday

Complete programs, grouped by days, shown on following pages

Saturday, Oct. 6, 1956

9:00 A.M. Statler Hotel

Seminar on Creep and Recovery

Defects and Recovery
By *J. Koehler*, University of Illinois

The Thermodynamics and Kinetics of Recovery
By *M. B. Bever*, Massachusetts Institute of Technology

Polygonization
By *W. R. Hibbard, Jr.*, General Electric Research Laboratories

2:00 P.M. Statler Hotel

Seminar on Creep and Recovery

Recovery of Electrical Resistivity
By *T. H. Blewitt*, Oak Ridge National Laboratories

Recovery of Mechanical Properties
By *E. C. W. Perryman*, Atomic Energy Establishment, Canada

Recovery of Internal Friction and Elastic Constants
By *A. S. Nowick*, Yale University

8:00 P.M. Statler Hotel

Seminar on Creep and Recovery

The Concept of Creep
By *E. N. daC. Andrade*, F.R.S., London, England

Sunday, Oct. 7, 1956

9:00 A.M. Statler Hotel

Seminar on Creep and Recovery

Theory of Creep
By *G. Schoeck*, Westinghouse Research Laboratories

The Role of the Boundary in Creep Phenomena
By *E. R. Parker* and *J. Washburn*, University of California

The Effect of Alloying Elements on Creep
By *J. C. Fisher*, General Electric Research Laboratories

2:00 P.M. Statler Hotel

Seminar on Creep and Recovery

The Spectrum of Activation Energies for Creep
By *J. E. Dorn*, University of California

Creep and Fracture
By *N. J. Grant*, Massachusetts Institute of Technology

Creep of Crystalline Non-Metals
By *J. B. Wachtman, Jr.*, National Bureau of Standards

Monday Morning,

9:00 A.M. Carter Hotel

Session on Research in Progress

9:00 A.M. Carter Hotel

Research Seminar – Embrittlement

Effect of Hydrogen on Alpha Titanium Alloys
By *G. A. Lenning*, Titanium Metals Corp. of America, *J. W. Spretnak*, Ohio State University, and *R. I. Jaffee*, Battelle Memorial Institute

Upper-Nose Temper Embrittlement of a Nickel-Chromium Steel
By *L. D. Jaffee* and *D. C. Buffum*, Jet Propulsion Laboratory, California Institute of Technology

On the Nature of Embrittlement Occurring While Tempering a Nickel-Chromium Alloy Steel
By *G. Bhat*, Crucible Steel Co. of America, and *J. F. Libsch*, Lehigh University

Observations on the Mechanical Properties of Hydrogenated Vanadium
By *B. W. Roberts* and *H. C. Rogers*, General Electric Co.

Effect of Small Amounts of Alloying Elements on the Ductility of Cast Molybdenum
By *L. E. Olds* and *G. W. P. Rengstorff*, Battelle Memorial Institute

9:00 A.M. Hollenden Hotel

Educational Session

Welcome
By *Hamilton Migel*, President, Society for Nondestructive Testing

Orientation
By *D. T. O'Connor*, Chairman, S.N.T. Educational Committee

Sources of Defects Located by Nondestructive Testing
By *Carl E. Betz*, Magnaflux Corp.

Radiography
By *W. D. Kiehle*, Eastman Kodak Co.

Radiographic Film Interpretation
By *L. L. Johnson*, Pratt & Whitney Aircraft

Fluoroscopy
By *W. R. Hampe*, Westinghouse Electric Corp.

Penetrant Testing
By *Taber DeForest*, Magnaflux Corp.

Eddy Current Testing
By *G. O. McClurg*, Magnaflux Corp.

9:30 A.M. Statler Hotel

Session on Iron

The Effect of Sub-Boundaries and Carbide Distribution on the Notch Toughness of an Ingot Iron
By *J. C. Danko* and *R. D. Stout*, Lehigh University

Notch Ductility of Malleable Irons
By *G. A. Sandoz*, *N. C. Howells*, *H. F. Bishop* and *W. S. Pellini*, Naval Research Laboratory

New Nodular Iron Process
By *Harry K. Ihrig*, Allis-Chalmers Mfg. Co.

The Deformation and Rupture of Gray Cast Iron
By *W. R. Clough*, Electro Metallurgical Co., and *M. E. Shank*, Massachusetts Institute of Technology

Oct. 8, 1956

9:30 A.M. Statler Hotel

Session on Plastic Deformation

Slip, Twinning and Fracture in Single Crystals of Iron
By *J. J. Cox*, E. I. du Pont de Nemours and Co., *G. T. Horne* and *R. F. Mehl*, Carnegie Institute of Technology

Dynamic Biaxial Stress-Strain Characteristics of Aluminum and Mild Steel
By *George Gerard* and *Ralph Papirno*, New York University

Some Exploratory Observations of the Tensile Properties of Metals at Very Low Temperatures
By *E. T. Wessel*, Westinghouse Research Laboratories

Effect of Strain Rate and Temperature on the Plastic Deformation of High-Purity Aluminum
By *T. A. Trozera, O. D. Sherby* and *J. E. Dorn*, University of California

10:00 A.M. Cleveland Hotel

President's Welcome and Presentation of Awards

10:30 A.M. Cleveland Hotel

Adams Lecture

10:30 A.M. Statler Hotel

Educational Lecture Course on Effect of Residual Elements on the Properties of Metals

Fundamental Considerations
By *E. R. Parker*, University of California

12:00 M. Statler Hotel

Battelle Alumni Luncheon

Monday Afternoon

1:45 P.M. Hollenden Hotel

Educational Session

Magnetic Particle Inspection
By *W. E. Thomas*, Magnaflux Corp.

Ultrasonic Testing, Contact Methods
By *Ralph W. Frank*, Sperry Products, Inc.

Ultrasonic Testing, Immersed Method
By *J. B. Morgan*, Aluminum Co. of America

Ultrasonic Testing, Resonance Method
By *P. K. Block*, Branson Instrument Co.

2:00 P.M. Statler Hotel

Session on Titanium

Relative High-Temperature Properties of the Hexagonal Close-Packed and Body-Centered Cubic Structures in Iodide Titanium
By *John Lunsford* and *N. J. Grant*, Massachusetts Institute of Technology

The Influence of Alloying on the Elastic Modulus of Titanium Alloys
By *W. H. Graft, D. W. Levinson* and *W. Rostoker*, Armour Research Foundation

A Study of the Air Contamination of Three Titanium Alloys
By *J. E. Reynolds, H. R. Ogden* and *R. I. Jaffee*, Battelle Memorial Institute

Effect of Sulphur on the Properties of Titanium and Titanium Alloys
By *L. W. Berger, D. N. Williams* and *R. I. Jaffee*, Battelle Memorial Institute

Relationship Between Heat Treatment, Structure and Mechanical Properties of a Titanium Alloy Containing 4% Cr and 2% Mo
By *A. W. Goldenstein* and *W. Rostoker*, Armour Research Foundation

2:00 P.M. Statler Hotel

Educational Lecture Course
Effect of Residual Elements on the Properties of Metals

Impurities in the Common Nonferrous Metals
By *F. N. Rhines*, Carnegie Institute of Technology

2:00 P.M. Carter Hotel

Symposium on Nuclear Metallurgy

Theory and Mechanism of Radiation Effects in Metals
By *G. H. Vineyard*, Brookhaven National Laboratory

Irradiation Effects on Physical Metallurgical Processes
By *D. E. Thomas*, Westinghouse Electric Corp.

Irradiation Effects in Reactor Materials
By *Douglas Billington*, Oak Ridge National Laboratory

2:00 P.M. Cleveland Hotel

Session on Inert-Arc Welding

Factors Affecting Melting Rate of Gas-Shielded Metal-Arc Welding
By *A. Lesnewich*, Air Reduction Co., Inc.

Shielding Gases for Inert-Gas Welding
By *W. H. Helmbrecht* and *G. W. Oyler*, Linde Air Products Co.

Inert-Gas Metal-Arc Welding of High-Pressure Valves
By *F. R. Zacheus*, Air Reduction Sales, Inc.

and Evening, Oct. 8, 1956

2:00 P.M. Carter Hotel

Research Summaries – Mechanical Properties

Influence of Silicon and Aluminum on the Properties of Hot Rolled Steels
By *R. H. Frazier, F. W. Boulger* and *C. H. Lorig*, Battelle Memorial Institute

Creep of Polycrystalline Nickel
By *J. Weertman* and *P. Shahinian*, Naval Research Laboratory

Study of the Effect of Gases on the Melting, Casting and Working of Palladium
By *R. H. Atkinson*, International Nickel Co., Inc.

Effect of Mo, W and V on the High-Temperature Rupture Strength of Ferritic Steel
By A. *E. Powers*, General Electric Co.

Ti — 36% Al as a Base for High-Temperature Alloys
By *J. B. McAndrew*, Armour Research Foundation, and *H. D. Kessler*, Titanium Metals Corp. of America

High-Strength Zirconium Alloy—Zirconium Plus 4% Tin Plus 1.6% Molybdenum
By *Walston Chubb*, Battelle Memorial Institute

Creep of Single Crystals and Polycrystals of Aluminum, Lead and Tin
By *C. D. Wiseman, O. D. Sherby* and *J. E. Dorn*, University of California

Effect of Melting and Casting Atmospheres on the Stress-Rupture Properties of Cast Nickel-Base Alloys
By *C. M. Hammond* and *R. A. Flinn*, University of Michigan

Aging in Complex Commercial Nickel-Chromium Alloys Hardened With Titanium and Aluminum
By *R. F. Wilde*, General Motors Corp., and *N. J. Grant*, Massachusetts Institute of Technology

Effect of Orientation on the Plastic Deformation of Aluminum Single Crystals and Bicrystals
By *R. S. Davis, R. L. Fleisher, J. D. Livingston* and *Bruce Chalmers*, Harvard University

2:00 P.M. Cleveland Hotel

Session on Structures

Behavior of Welded Built-Up Beams Under Repeated Loads
By *J. E. Stallmeyer, W. H. Munse* and *B. J. Goodal*, University of Illinois

Welded Open-Web Expanded Beams
By *M. Altfillisch, B. R. Cooke* and *A. A. Toprac*, University of Texas

Welded Reinforcement of Openings in Structural Steel Tension Members
By *R. A. Hechtman* and *D. D. Vasarhelyi*, University of Washington

2:00 P.M. Cleveland Hotel

Session on Weldability and Research

Notch Toughness Characteristics of Submerged-Arc Weld Deposits
By *I. L. Stern, N. A. Kahn* and *H. Nagler*, New York Naval Shipyard

Effect of Metallurgical Variables on Transition Behavior in Charpy Slow-Bend and Impact Tests
By *C. E. Hartbower*, Watertown Arsenal Laboratories

Mild Steel Weld-Metal Porosity
By *R. D. Stout*, Lehigh University, and *J. T. Ballass*, Electric Boat Div. of General Dynamics Corp.

6:00 P.M. Cleveland Hotel

President's Reception

Tuesday Morning,

9:00 A.M. Carter Hotel

Research Seminar – Crystalline Imperfections and Mechanical Behavior

Delayed Yielding in a Substitutional Solid Solution Alloy
By *L. A. Shepard* and *J. E. Dorn*, University of California

Control of Strain Aging in Alpha Iron
By *E. R. Morgan*, Jones and Laughlin Steel Corp., and *J. C. Shyne*, Ford Motor Co.

Recovery of Cold Worked High-Purity Aluminum-Magnesium Alloys
By *E. C. W. Perryman*, Atomic Energy of Canada, Ltd.

Temperature Dependence of Annealing Phenomena in a Cold Rolled Aluminum Single Crystal
By *A. H. Lutts* and *P. A. Beck*, University of Illinois

Investigation of the Effect of Solutes on the Grain-Boundary Stress Relaxation Phenomenon
By *S. Weinig*, New York University, and *E. S. Machlin*, Columbia University

Some Observations on the Structure of Grain Boundary Fracture Surfaces
By *H. C. Chang* and *N. J. Grant*, Massachusetts Institute of Technology

9:00 A.M. Statler Hotel

Session on Steel

Temperability of Steels
By *L. D. Jaffe*, Jet Propulsion Laboratory, California Institute of Technology, and *Edward Gordon*, United Gas Corp.

The Temperature Dependence of the Hardness of Pure Iron and Various Ferritic Steels
By *F. Garofalo* and *D. C. Marsden*, U.S. Steel Corp. and *G. V. Smith*, Cornell University

The Influence of Bainite on Mechanical Properties
By *R. F. Hehemann*, *V. Luhanov* and *A. R. Troiano*, Case Institute of Technology

On the Cooling Transformations in Some 0.40% Carbon Constructional Alloy Steels
By *D. J. Blickwede* and *R. C. Hess*, Bethlehem Steel Co.

9:00 A.M. Carter Hotel

Symposium on Titanium

Panel Discussion on Sponge and Mill Production Economics
Speaker: *H. H. Kellogg*, Columbia University
Panelists: *W. E. Lusby, Jr.*, E. I. du Pont de Nemours and Co.
T. W. Lippert, Titanium Metals Corp. of America
P. Alspaugh, Electro Metallurgical Co.
V. W. Whitmer, Republic Steel Corp.
D. W. Kaufmann, Rem-Cru Titanium, Inc.
F. Vandenburgh, Mallory-Sharon Titanium Corp.

Panel Discussion on Fabrication Economics
Speaker: *S. A. Gordon*, Battelle Memorial Institute
Panelists: *G. Fairbairn*, North American Aviation, Inc.
W. H. Sharp, Pratt and Whitney Aircraft Div., United Aircraft Corp.
A. L. Rustay, Wyman-Gordon Co.
R. A. Paetz, Thompson Products, Inc.
W. R. Carpenter, Convair Div., General Dynamics Corp.

9:00 A.M. Hollenden Hotel

First Session on Developments in Nondestructive Testing Methods

Inspection of Small-Diameter Tubing by Eddy Current Methods
By *John W. Allen* and *Robert B. Oliver*, Oak Ridge National Laboratory

Oct. 9, 1956

Broad Beam Attenuation Data for Concrete for 70 to 250 Kvp. X-Rays
By *E. Dale Trout*, X-Ray Dept., General Electric Co.

Design and Application of a Portable X-Ray Spectrograph
By *Irwin I. Bessen*, North American Philips Co., Inc.

Standardization and Applications of Ultrasonic Surface Wave Inspection
By *G. J. Binczewski*, Kaiser Aluminum & Chemical Corp.

Data Extraction in Nondestructive Testing
By *H. N. Staats*, Applied Research, Inc.

9:30 A.M. Cleveland Hotel

Session on Aircraft

Design Requirements for Fusion Welding Titanium in Aircraft Applications
By *R. Meredith*, North American Aviation

Fusion Welding of Magnesium-Thorium Alloys
By *F. K. Lampson*, Marquardt Aircraft

Weld Planishing Improves Production of Aircraft Parts
By *H. L. Mederith*, Airline Welding and Engineering Co.

9:30 A.M. Cleveland Hotel

Session on Weldability and Research

Brittle Fracture Initiation Tests
By *C. Mylonas* and *D. C. Drucker*, Brown University

Brittle Fracture Propagation in Wide Steel Plates
By *W. J. Hall, R. J. Mosborg* and *V. J. McDonald*, University of Illinois

The Effect of Microstructure on Notch Toughness—Part IV
By *J. C. Danko, R. D. Stout* and *J. H. Gross*, Lehigh University

9:30 A.M. Cleveland Hotel

Session on Design and Inspection

How Welding Can Further Bridge Building Progress
By *O. Blodgett*, Lincoln Electric Co.

Industrial Radiography by Gamma-Ray Projection From Radioactive Isotopes
By *C. M. Dick*, Metal & Thermit Corp.

Greater Acceptance of Welding Through the Use of Inspection Methods
By *J. R. Harrer*, Magnaflux Corp.

9:30 A.M. Statler Hotel

Educational Lecture Course on Effect of Residual Elements on the Properties of Metals

Residual Elements in Steel
By *J. W. Halley*, Inland Steel Co.

9:30 A.M. Statler Hotel

Joint session with on Furnace Atmospheres – Their Properties, Application, Control and Usage

Review of Atmospheres—Their Types
By *C. H. Vaughan*, Electric Furnace Co.

Review of Atmospheres—Their Applications
By *Clarence E. Peck*, Westinghouse Electric Corp.

Types of Controllers Available
By *W. Besselman*, Leeds & Northrup Co.

Methods of Controlling Atmosphere Converters
By *Walter Holcroft*, Holcroft & Co.

Methods of Controlling Atmosphere in Furnaces
By *Orville Cullen*, Surface Combustion Corp.

Atmosphere Furnaces—Their Safe Operation
By *Norman H. Davies*, North American Mfg. Co.

12:00 M. Statler Hotel

Awards Luncheon

Speaker: *C. M. White*, Chairman of the Board, Republic Steel Corp.

Tuesday Afternoon

1:30 P.M. Hollenden Hotel

Session on Nondestructive Testing in the Petroleum and Chemical Industries

Quality Characteristics of Chemical Equipment and Their Control Through Nondestructive Testing
By *C. J. Veith,* E. I. du Pont de Nemours & Co., Inc.

Inspection of Piping
By *H. Thielsch,* Grinnel Co., Inc.

Ultrasonic Inspection in the Oil Refining and Related Industries
By *D. J. Evans,* Engineering Test Services, Inc.

A Fast, Economical Inspection for Drill Pipe
By *F. M. Wood,* Tuboscope Co.

2:00 P.M. Statler Hotel

Session on Steel

Impact Characteristics and Mechanical Properties of Leaded and Non-Leaded C-1050 and C-1141 Steels
By *A. P. Weaver,* Inland Steel Co.

Relation of Inclusions to the Fatigue Properties of S.A.E. 4340 Steel
By *H. N. Cummings, F. B. Stulen* and *W. C. Schulte,* Curtiss-Wright Corp.

Effect of Silicon on Transverse Properties and on Retained Austenite Content of High-Strength Steels
By *John Vajda, J. J. Hauser* and *Cyril Wells,* Carnegie Institute of Technology

Bend-Tensile Relationships for Toolsteels at High Strength Levels
By *J. C. Hamaker, Jr., V. G. Strang* and *G. A. Roberts,* Vanadium-Alloys Steel Co.

2:00 P.M. Carter Hotel

Research Summaries — Atom Movements and Structure

Basal Plane Development in Electrodeposited Hexagonal Close-Packed Metals—Zinc, Titanium, Zirconium
By *W. R. Opie,* National Lead Co.

Surface Activity Methods for the Determination of Diffusion Coefficients in Solids
By *R. H. Condit* and *C. E. Birchenall,* Princeton University

X-Ray Diffraction Determination of the Coefficients of Expansion of Alpha-Uranium
By *J. R. Bridge, C. M. Schwartz* and *D. A. Vaughan,* Battelle Memorial Institute

Solubility of Boron in Fe_3C and Variation of Saturation Magnetization, Curie Temperature, and Lattice Parameter of $Fe_3(C,B)$ With Composition
By *M. E. Nicholson,* University of Minnesota

Crystal Structure of Delta-Prime Plutonium and the Thermal Expansion Characteristics of Delta, Delta-Prime and Epsilon Plutonium
By *F. H. Ellinger,* Los Alamos Scientific Laboratory

Structure of the Transition Phase, Omega, in Titanium-Chromium Alloy
By *A. E. Austin* and *J. R. Doig,* Battelle Memorial Institute

Neutron Diffraction Study of Textures in Drawn Body-Centered Cubic Metals
By *R. A. Swalin,* University of Minnesota, and *A. H. Geisler* (deceased)

Relative Interfacial Energies of Symmetrical Tilt Grain Boundaries in Silver
By *K. T. Aust,* General Electric Co.

2:00 P.M. Cleveland Hotel

Session on Titanium

An Investigation of the Weldability of Ti-6% Al-4% V
By *D. M. Daley, Jr.* and *C. E. Hartbower,* Watertown Arsenal Laboratories

Problems Involved in Spot Welding Titanium to Other Metals
By *F. W. McBee, Jr.* and *J. H. Henson,* Defense Research Laboratory, and *L. R. Benson,* University of Texas.

Effects of Interstitial Elements on Welds in Alpha-Beta Titanium Alloys
By *W. J. Lewis, M. L. Kohn, G. E. Faulkner* and *P. J. Rieppel,* Battelle Memorial Institute

and Evening, Oct. 9, 1956

2:00 P.M. Carter Hotel

Symposium on Titanium

Panel Discussion on State of Analytical Development
Speaker: S. *Vigo*, Watertown Arsenal
Panelists: *T. D. McKinley*, E. I. du Pont de Nemours and Co., Inc.
J. E. Griffin, Mallory-Sharon Titanium Corp.
H. T. Clark, Jr., Rem-Cru Titanium Inc.
A. F. Ernster, Ford Motor Co.
W. A. Dupraw, National Research Corp.
M. J. Miles, Titanium Metals Corp. of America

Panel Discussion on Practical Problems Association With the Control of Interstitials
Speakers: *L. S. Busch*, Mallory-Sharon Titanium Corp.
H. Brown, Solar Aircraft Co.
C. Handova, North American Aviation, Inc.
Panelists: *H. T. Clark, Jr.*, Rem-Cru Titanium, Inc.
T. Perry, Republic Steel Corp.
S. A. Herres, Titanium Metals Corp. of America
J. A. King, Thompson Products of Canada

2:00 P.M. Statler Hotel

Educational Lecture Course on Effect of Residual Elements on the Properties of Metals

Newer Metals — Titanium, Zirconium, Molybdenum and Chromium
By *D. J. McPherson*, Armour Research Foundation

2:00 P.M. Cleveland Hotel

Session on Inert-Arc Welding

Selection of Proper Inert-Gas-Shielded Arc Welding Process
By *C. J. Sullivan* and *I. D. Holster, Jr.*, Air Reduction Sales Co.

Consumable-Electrode Inert-Gas Welding With Small-Diameter Wires
By *K. E. Richter* and *J. F. M. Essig*, Linde Air Products Co.

Inert-Gas-Shielded Metal-Arc Spot Process
By *J. W. Kehoe* and *H. J. Bichsel*, Westinghouse Electric Corp.

2:00 P.M. Cleveland Hotel

Symposium on Metallizing

Surfacing and Build-up
By *R. J. McWaters*, Metallizing Engineering Co., Inc.

Ceramic Coatings
By Representative of Norton Co.

Corrosion
By *E. T. Englehart*, Aluminum Research Laboratories

Combination Coatings
By *C. J. Breitenstein*, Metal-Cladding, Inc.

4:30 P.M. Cleveland Hotel

Educational Lecture Series

6:30 P.M. Hollenden Hotel

Hospitality Hour, Banquet and Awards

Evening Carter Hotel

Fellowship Dinner

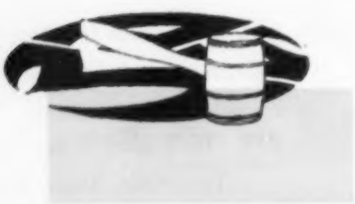
Wednesday Morning,

7:30 A.M. Statler Hotel

Chapter Chairmen's Breakfast

9:00 A.M. Statler Hotel

Annual Meeting



9:00 A.M. Hollenden Hotel

Session on Nondestructive Testing of Nuclear Reactor Components

Nondestructive Testing Problems in the Nuclear Reactor Field
By *S. McLain* and *W. J. McGonnagle*, Argonne National Laboratory, and *E. C. Wood*, General Electric Co.

Basic Principles and Techniques of Eddy Current Testing
By *H. L. Libby*, General Electric Co., Hanford Atomic Products Operation

Ultrasonic Methods and Techniques Used at the Savannah River Laboratory
By *R. W. Leep and J. D. Ross*, E. I. du Pont de Nemours & Co., Inc.

Inspection of Small-Diameter Tubing for Nuclear Reactor Applications
By *R. B. Oliver*, Oak Ridge National Laboratory

Ultrasonic Scanning and Recording Equipment
By *W. N. Beck*, Argonne National Laboratory

9:00 A.M. Carter Hotel

Research Summaries – Kinetics and Thermodynamics

Structure-Dependent Corrosion of Cu_3Au—Experiments Relating to the Mechanism of Stress Cracking of Homogeneous Solid Solutions
By *Robert Bakish*, Sprague Electric Co., and *W. D. Robertson*, Yale University

Growth of External Copper Layers During the Internal Oxidation of Dilute Cu-Al Alloys in a Cuprous Oxide-Copper Pack
By *D. L. Wood*, General Electric Co.

Free Energy of Formation of Mn_7C_3 From Vapor-Pressure Measurements
By *C. L. McCabe* and *R. G. Hudson*, Carnegie Institute of Technology

Oxygen in Liquid Iron-Nickel Alloys
By *H. A. Wriedt*, U. S. Steel Corp., and *John Chipman*, Massachusetts Institute of Technology

9:00 A.M. Carter Hotel

Research Summaries – Transformation

Study of the Iron-Silicon Order-Disorder Transformation
By *F. W. Glaser*, Alloy Precision Castings Co., and *W. Ivanick*, Schwarzkopf Development Corp.

Structural Changes During the Aging in an Aluminum-Magnesium-Zinc Alloy
By *L. F. Mondolfo*, Illinois Institute of Technology, *N. A. Gjostein*, Carnegie Institute of Technology, and *D. W. Levinson*, Armour Research Foundation

Sympathic Nucleation of Ferrite
By *H. I. Aaronson* and *C. Wells*, Carnegie Institute of Technology

Electrical Resistivities and Phase Transformations of Lanthanum, Cerium, Praseodymium, and Neodymium
By *F. H. Spedding, A. H. Daane* and *K. W. Herrmann*, Iowa State College

Oct. 10, 1956

9:30 A.M. Cleveland Hotel

Session on Brazing and Surfacing

Silver Brazing Lap Joints in Stainless Steel Tubing
By *G. H. Bohn*, Linde Air Products Co.

Basic Characteristics of Some Heat Resistant Brazing Filler Materials
By *W. Chang*, General Electric Co.

Longer Service Life Through Hard Facing for Petroleum Industry Equipment
By *H. S. Gonser*, Wall Colmonoy Corp.

9:30 A.M. Cleveland Hotel

Session on Filler Metal

A New Nodular Cast Iron Welding Rod for Foundries and Fabricators
By *R. O. Day, J. S. Snyder and H. V. Inskeep*, Linde Air Products Co.

Coating Ingredients Influence on Surface Tension, Arc Stability and Bead Shape
By *T. H. Hazlett* and *Earl R. Parker*, University of California

Electrode Control in an Alloy Pressure Vessel Plant
By *W. W. Weber*, Colonial Iron Works Co.

9:30 A.M.

**Plant Tour to
Euclid Div., General Motors Corp.**

9:30 A.M. Cleveland Hotel

Session on Piping and Pipelines

Status of Efforts to Develop Mechanized Pipeline Welding Methods
By *P. S. Reed*, Oil and Gas Journal

Automatic Welding of Piping
By *H. Thielsch* and *F. R. Jerome, Jr.*, Grinnell Co., Inc.

Automatic Welding Applications at the Whiting Refinery
By *R. C. Wheeler* and *R. M. Kolb*, Standard Oil Co.

10:00 A.M. Statler Hotel

Campbell Memorial Lecture

Metallurgy at Low Temperatures
By *Charles S. Barrett*, Institute for the Study of Metals, University of Chicago

12:00 M. Statler Hotel

Canadian Luncheon

12:00 M. Carter Hotel

Powder Metallurgy Luncheon

12:00 M. Statler Hotel

University Alumni Luncheons

Wednesday Afternoon and

1:30 P.M. Hollenden Hotel

Mehl Honor Lecture and National Meeting

Standards for Nondestructive Testing Practices
By *N. L. Mochel*, Westinghouse Electric Corp.

2:00 P.M. Statler Hotel

Session on Stainless

Precipitation Reactions in Austenitic Cr-Mn-C-N Stainless Steels
By *Chi-Mei Hsiao* and *E. J. Dulis*, Crucible Steel Co. of America

Martensitic Transformation in the Machining of Austenitic Stainless Steel
By *E. F. Erbin*, Titanium Metals Corp., *E. R. Marshall*, University of Vermont, and *W. A. Backofen*, Massachusetts Institute of Technology

Transformation Products in Cold Worked Austenitic Manganese Steel
By *R. K. Buhr* and *S. L. Gertsman*, Department of Mines and Technical Surveys, Ottawa, and *James Reekie*, Northern Electric Co.

Metallography of Titanium-Stabilized 18-8 Stainless Steel
By *T. V. Simpkinson*, Republic Steel Corp.

Phase Relationships and Mechanical Properties of Some Iron-Chromium-Carbon-Nitrogen Alloys
By *G. F. Tisinai* and *C. H. Samans*, Standard Oil Co.

2:00 P.M. Carter Hotel

Symposium on Magnetism

Fundamentals of Magnetism
By *J. B. Goodenough*, Massachusetts Institute of Technology

Kinetics of Magnetization
By *D. S. Rodbell*, General Electric Co.

Metallurgy of Magnetic Materials
By *J. J. Becker*, General Electric Co.

2:00 P.M. Carter Hotel

Research Summaries – Alloy Systems

Study of Ferrous Ternary Diagrams in Relation to Magnetic Interactions; the FeNiAl System
By *U. H. Roesler*, Westinghouse Research Laboratories

Melting Point Determination of Hafnium, Zirconium and Titanium
By *D. K. Deardorff* and *E. T. Hayes*, U.S. Bureau of Mines

Gamma Loop Studies in the Iron-Silicon and Iron-Silicon-Titanium Systems
By *G. G. Bentle* and *W. P. Fishel*, Vanderbilt University

Uranium-Bismuth System
By *R. J. Teitel, Brookhaven* National Laboratory

Uranium-Silicon Alloys
By *A. E. Kaufmann*, Nuclear Metals, Inc., *B. D. Cullity*, University of Notre Dame, and *G. Bitsianes*, University of Minnesota

Uranium-Zinc System
By *P. Chiotti, H. H. Klepfer* and *K. J. Gill*, Iowa State College

Constitution of Nickel-Rich Quaternary Alloys of the Nickel-Chromium-Titanium-Aluminum System
By *A. Taylor*, Westinghouse Research Laboratories

Solid Solubility of Carbon in Chromium
By *W. H. Smith*, General Electric Co.

2:00 P.M. Cleveland Hotel

Session on Resistance Welding

Recent Developments in Magnetic Force Welding
By *E. J. Funk*, Precision Welder & Flexopress Corp.

Regulated and Programmed Resistance Welding Control Systems
By *C. Sinclair*, General Electric Co.

Finish Mash Seam Welding
By *M. L. Begeman* and *W. J. Allen*, University of Texas

Evening, Oct. 10, 1956

2:00 P.M. Statler Hotel

Session on Nuclear Materials

Creep and Stress-Rupture Properties of Zirconium; Effect of Annealing Treatment
By *R. W. Guard* and *J. H. Keeler*, General Electric Co.

Transformation Kinetics of Uranium-Niobium and Ternary Uranium-Molybdenum-Base Alloys
By *R. J. Van Thyne* and *D. J. McPherson*, Armour Research Foundation

Transformation Kinetics of Uranium-Molybdenum Alloys
By *R. J. Van Thyne* and *D. J. McPherson*, Armour Research Foundation

The Plastic Deformation of Uranium on Thermal Cycling
By *H. H. Chiswik*, Argonne National Laboratory

2:00 P.M. Cleveland Hotel

Session on Stainless Steel

Properties of Austenitic Chromium-Manganese Stainless Steel Weld Metal
By *W. T. DeLong* and *H. F. Reid*, McKay Co.

The Plastic Ductility of Welded Joints in Austenitic Steel Piping at 1200°
By *R. W. Emerson* and *R. W. Jackson*, Pittsburgh Piping and Equipment Co.

Further Studies on Stainless Steel Hot Cracking
By *H. Rischall* and *P. P. Puzak*, Naval Research Laboratory

2:00 P.M.

Field Trip to National Carbon Co.

2:00 P.M. Cleveland Hotel

Session on Pressure Vessels

Fabrication of Inert-Gas Welded Aluminum Tanks and Pressure Vessels
By *R. J. Franz* and *Amel R. Meyer*, Graver Tank and Mfg. Co., Inc.

The Properties of Pressure-Vessel Steels in Heavy Sections
By *J. H. Gross* and *R. D. Stout*, Lehigh University

Investigation of a Pressure Vessel Failure
By *J. Heuschkel*, Westinghouse Research Laboratories

4:30 P.M. Cleveland Hotel

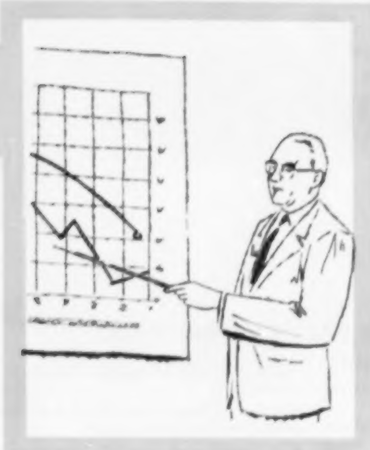
Educational Lecture Series

7:00 P.M.

Field Trip to Ford Motor Co.

7:00 P.M. Cleveland Hotel

Annual Dinner



Thursday Morning,

9:30 A.M. Statler Hotel

Session on High Temperature

Effect of Sigma Phase on Co-Cr-Mo Base Alloys
By *Ronald Silverman*, Sylvania Electric Co., *William Arbiter*, Nuclear Development Corp. of America, and *Frank Hodi*, U. S. Army

An Austenitic Alloy for High-Temperature Use
By *R. W. Guard* and *T. A. Prater*, General Electric Research Laboratory

High-Temperature Rupture-Strength Properties of Chromium-Nickel Stainless Steels Containing Titanium and Boron
By *J. Salvaggi* and *L. A. Yerkovich*, Cornell Aeronautical Laboratories, Inc.

Effect of Environment on Creep-Rupture Properties of Some Commercial Alloys
By *Paul Shahinian*, Naval Research Laboratory

The Influence of Molybdenum on the Phase Relationships of a High-Temperature Alloy
By *H. J. Beattie, Jr.* and *F. L. VerSnyder*, General Electric Co.

9:30 A.M. Cleveland Hotel

Session on Piping and Tubing

Study of Interrupted Welding of Heavy-Wall Steam Pipe
By *I. A. Rohrig*, *J. O. Smith* and *E. G. Shifrin*, Detroit Edison Co.

Welding Heavy-Wall Carbon-Steel Pipe With CO_2 Shielding Gas
By *A. B. Dunning*, General Electric Co.

Effect of Zinc Phosphate Coatings on Flash Welding of Steel Tubing
By *J. F. Young* and *A. Phillips*, Douglas Aircraft Co., Inc.

9:30 A.M. Statler Hotel

Educational Lecture Course on Factors Affecting the Fatigue Endurance of Carburized Steel

Introduction
By *J. B. Bidwell*, General Motors Corp.

Physical Metallurgy of Carburized Steels
By *G. H. Robinson*, General Motors Corp.

9:00 A.M. Hollenden Hotel

Second Session on Developments in Nondestructive Testing Methods

The Ultrasonic Micrometer—a New Nondestructive Test Tool
By *H. A. Rocha*, Large Steam Turbine-Generator Dept., General Electric Co.

Production Inspection of Pipe and Tubing by the Immersed Ultrasound Method
By *Robert B. Oliver*, *R. W. McClung* and *J. K. White*, Oak Ridge National Laboratory

Field Performance of TVX System
By *J. E. Jacobs* and *A. L. Pace*, X-Ray Dept., General Electric Co.

Fluoroscopy With Electronic Image Intensification
By *A. L. Gobus*, Instruments Div., North American Philips Co., Inc.

Oct. 11, 1956

9:30 A.M. Carter Hotel

Conference on Thorium (Jointly with A.E.C.) Properties of the Metal

The Role of Thorium Metal in the Nuclear Field
By *John P. Howe*, Atomics International

Non-Nuclear Applications of Thorium Metal Other Than in Magnesium Technology
By *William C. Lilliendahl*, Westinghouse Electric Corp.

The Uses of Thorium in Magnesium Technology
By *T. E. Leontis*, Dow Chemical Co.

The Production of Thorium Compounds
By *Morton Smutz* and *John Barghusen*, Ames Laboratory, A.E.C.

Reduction of Thorium Tetrafluoride by Calcium
By *Harley A. Wilhelm*, Ames Laboratory, A.E.C.

Consumable-Electrode Arc Melting of Thorium
By *A. H. Roberson*, U.S. Bureau of Mines

Powder Metallurgy of Thorium
By *B. Kopelman*, Sylvania Electric Co.

Spectrographic Analysis of Thorium Metal
By *V. A. Fassel* and *Edward DeKalb*, Ames Laboratory, A.E.C.

Chemical Analysis of Thorium Metal
By *C. J. Rodden* and *Morris W. Lerner*, New Brunswick Laboratory, A.E.C.

Purification of Thorium Metal by the Iodide or Hot-Wire Process
By *Icor E. Campbell*, Battelle Memorial Institute

The Electrolytic Refining of Thorium
By *R. A. Noland*, Argonne National Laboratory

9:30 A.M. Statler Hotel

Discussion Forum on Die Wear and Die Life in Stamping Operations*

*Morning session by invitation.

9:30 A.M.

Plant Tour to Chevrolet-Cleveland Div. of General Motors Corp.

9:30 A.M. Cleveland Hotel

Session on Welding and Cutting

Aspects of Crack Sensitivity in Machinable Deposits on Cast Iron
By *J. Broderick*, *R. D. Wasserman* and *J. F. Quaas*, Eutectic Welding Alloys Corp.

Fundamental Concepts of Oxygen Cutting
By *R. L. Stoecker* and *W. B. Moen*, Air Reduction Co., Inc.

Transverse Cracking Resulting From Oxygen Cutting
By *N. N. Breyer*, Continental Foundry & Machine Div., Blaw-Knox Co.

9:30 A.M. Cleveland Hotel

Session on Aluminum

Chlorine Additions in Inert-Gas Metal-Arc Welding of Aluminum
By *A. R. Pfluger* and *M. B. Kasen*, Kaiser Aluminum and Chemical Corp., and *L. A. Cook*, Ravens Metal Products, Inc.

The Thermal Stability of Cold Butt Welds in Aluminum and Copper
By *W. H. Bruckner* and *J. H. Sayles*, University of Illinois

Fabricating Aluminum With Other Metals
By *K. V. Lutz*, All-State Welding Alloys Co., Inc.

10:00 A.M. Public Auditorium

Session on Automation in Literature Research

A Report on the A.S.M. Mechanized Literature Searching Project
By *Allen Kent*, Center for Documentation and Communication Research, Western Reserve University

Thursday Afternoon

1:05 P.M. Public Auditorium

Open Discussion Forum on Die Wear and Die Life in Stamping Operations

1:30 P.M. Hollenden Hotel

Session on Nondestructive Testing of Aircraft

Relationship Between Defect Orientation and Ultrasonic Indications
By *R. E. Kleint*, North American Aviation, Inc.

Classification of Contractor's Standards for the Procurement of Bureau of Aeronautics Magnesium and Aluminum Castings
By *E. L. Criscuolo* and *N. Modine*, U.S. Naval Ordnance Laboratory

Radiography in Production Control and Inspection of Reliable Subminiature Tubes
By *E. A. Kolm*, Raytheon Mfg. Co.

X-Ray of Aircraft Components at the Aircraft for Maintenance Purposes
By *F. R. Richardson*, U.S. Air Force

2:00 P.M. Statler Hotel

Educational Lecture Course on Factors Affecting the Fatigue Endurance of Carburized Steel

Residual Stresses in Carburized Steels
By *W. S. Coleman*, General Motors Corp.

Fatigue Durability of Carburized Steels
By *R. L. Mattson*, General Motors Corp.

Summary
By *R. F. Thomson*

2:00 P.M. Carter Hotel

Conference on Thorium (Jointly with A.E.C.) Properties of the Metal

Physical Constants, Crystal Structure and Thermodynamic Properties
By *J. F. Smith*, Ames Laboratory, A.E.C.

Atomic Structure of Thorium, Its Electron Energy and Other Considerations as to Solid-State Physics
By *T. G. Berlincourt*, Atomics International

Preferred Orientation in Thorium
By *L. K. Jetter* and *Carl J. McHargue*, Oak Ridge National Laboratory

Fabrication and Cladding of Thorium Metal
By *John H. Frye* and *Jack Cunningham*, Oak Ridge National Laboratory

Recrystallization and Grain Growth in Thorium Metal
By *Edward J. Boyle*, Electro Metallurgical Co.

Mechanical Properties of Thorium Metal and High-Thorium Alloys
By *John Milko* and *Robert E. Adams*, Oak Ridge National Laboratory

Corrosion Resistance of Thorium Metal and High-Thorium Alloys
By *H. A. Pray* and Associates, Battelle Memorial Institute

Metallography of Thorium
By *Harriet P. Roth*, Nuclear Metals, Inc.

Irradiation Damage in Thorium Metal
By *Frank G. Foote*, Argonne National Laboratory

Thorium Alloy Systems
By *H. A. Saller* and *Frank A. Rough*, Battelle Memorial Institute

Hazards Associated With Thorium Metallurgy
By *Adolph Voight* and *Milo Voss*, Ames Laboratory, A.E.C.

and Evening, Oct. 11, 1956

2:00 P.M. Statler Hotel

Session on High Temperature

The Mechanical Properties of Iron-Aluminum Alloys
By *W. Justusson, V. F. Zackay* and *E. R. Morgan*, Ford Motor Co.

Some High-Temperature Oxidation Characteristics of Nickel With Chromium Additions
By *G. E. Zima*, International Nickel Co., Inc.

The Mechanical Properties of Swaged Iodide-Base Chromium and Chromium Alloys
By *D. J. Maykuth* and *R. I. Jaffee*, Battelle Memorial Institute

Effect of Dispersion of Alpha Phase on the High-Temperature Fatigue Properties of Alpha-Beta Brass
By *J. E. Breen*, Naval Research Laboratory, and *J. R. Lane*, National Research Council

Aging Reactions in Certain Superalloys
By *W. C. Hagle* and *H. J. Beattie, Jr.*, General Electric Co.

2:00 P.M. Public Auditorium

Publications on Industrial Uses of Atomic Energy

The Literature of Industrial Power Uses of Atomic Energy
By *Fred E. Croxton* and *Philip Leslie*, Goodyear Atomic Corp.

The Literature of Radiation Effects on Materials
By *James B. Dodd*, Babcock & Wilcox Co.

The Literature of Radioactive Testing Techniques
(Speaker to Be Announced)

2:15 P.M. Public Auditorium

Open Discussion Forum on Die Wear and Die Life in Stamping Operations

6:30 P.M. Manger Hotel

Dinner and Social Hour

7:30 P.M. Statler Hotel

Annual Banquet

Speaker: *John R. Dunning*, Dean of Engineering, Columbia University

Friday Oct. 12, 1956

9:00 A.M.

Field Trip to Penton Publishing Co.

9:30 A.M. Cleveland Hotel

Session on Molybdenum and Zirconium

Ductility of Tungsten-Arc Welds in Molybdenum
By *R. E. Monroe, N. E. Weare* and *D. C. Martin,* Battelle Memorial Institute

The Influence of Nitrogen on the Ductility of Molybdenum Welds
By *W. N. Platte,* Westinghouse Electric Corp.

Notch Slow-Bend Testing of Zirconium and Zircaloy-2
By *R. G. Wheeler,* General Electric Co.

9:30 A.M. Cleveland Hotel

Session on Shop Management

Organization of Shop Management for Quality Welding
By *W. B. Bunn,* M. W. Kellogg Co.

Maintaining Workmanship Standards for Quality Welding
By *Howard B. Cary,* Marion Power Shovel Co.

9:30 A.M. Cleveland Hotel

Session on Processes

The Motor Arc Welding Process
By *C. C. Stone* and *R. A. Noland,* Argonne National Laboratory

High-Frequency Continuous Seam Welding of Ferrous and Non-Ferrous Tubing
By *H. B. Osborn, Jr.,* Tocco Div., Ohio Crankshaft Co.

Developed Procedures for the Flexible Electrode Submerged-Arc Welding Process
By *M. H. Fritsche,* Westinghouse Electric Corp.

12:00 M. Public Auditorium

Distinguished Service Luncheon for 25-Year Members and Students

2:00 P.M.

Tour of Thompson Products Co.

EXHIBITOR LISTING

A

Booth

Aaron Machinery Co., Inc. 2224

Acetogen Gas Co. 2656
Gas mixing unit for cutting and brazing applications.

Acme Steel Co. 1933
Metal stitchers and steel strapping.

Acme Tool Co. 715
Universal lathe tool holder and inspection tools.

Adamas Carbide Corp. 1747
Sintered aluminum oxide cutting tool material and tungsten carbide.

Advance Glove Mfg. Co. 2803
Complete line of safety gloves.

Aeronautical Service-Engineering 2751
Aircraft and helicopter parts shot-peened.

Aeroprojects Inc. 2333
Ultrasonic welding and brazing equipment.

Ajax Electric Co. 1609
Salt bath furnace equipment.

Ajax Electrothermic Corp. 1609
High-frequency induction furnaces.

Ajax Engineering Corp. 1609
Low-frequency induction melting furnaces.

Aldridge Industrial Oils Inc. 525
Heat treating and metalworking compounds.

Al-Fin Div., Fairchild Engine & Airplane Corp. 2324
Molecularly bonded bimetallic castings.

Allegheny Ludlum Steel Corp. 451
Heat and corrosion resistant alloys, tool and die steels and cemented carbides.

Allis-Chalmers Mfg. Co., Buda Div. 2509
Openhearth diesel fork lift truck.

Allison Div. 1816
Abrasive cutting wheels.

Alloy Engineering & Casting Co. 936
Heat and corrosion resistant castings.

American Brake Shoe Co. 215
Heat resistant and precision engineered castings.

American Cast Iron Pipe Co. 2144
Centrifugal castings.

American Chain & Cable Co. 1816
See Allison Div., Campbell Machine Div. and Wilson Mechanical Instrument Div.

American Chemical Paint Co. 2332
Metalworking and finishing compounds.

American Cyanamid Co. 1501
Heat treating compounds and metallurgical additives.

American Cystoscope Makers, Inc. 2836
Borescopes and optical flats.

American Gas and Electric Co. 2007
Products of companies served by the American Gas and Electric Co.

American Gas Assoc. 2859
Industrial gas furnaces, ovens and burners.

American Gas Furnace Co. 2841
Automatic heat treating equipment.

American Herforder Corp. 2033

American Machinist 2406

American Metal Market 1745
American Metal Market and *Metal Statistics.*

American Optical Co. 1136
Metallographic equipment.

American Positive Grip Vise Corp. 2773
Ampogrip holding fixtures.

American Pullmax Co. Inc. 2521
Universal shearing and forming machines.

American Silver Co., Inc. 930
Very thin, close tolerance metal strip.

American Society for Metals 1706
Information on World Metallurgical Congress and Metals Engineering Inst.

Amperex Electronic Corp. 2635
Electronic tubes for industrial applications.

Apex Tool & Cutter Co., Inc. 2816
Inserted tooth type milling cutters.

Applied Research Laboratories 2112
Spectrographic equipment.

Arcweld Manufacturing Co. 2302
High-temperature testing equipment.

Aro Spot Welder Div. 2733
Portable spot welders.

Ashworth Bros., Inc. 2660
Wire belts for heat treating and material handling.

Assembly Products, Inc. 1702
Temperature controls and meter-relays.

Atlas Mineral Products Co. 2729
Corrosion resistant cements and plastics.

Audubon Wire Cloth Corp. 2728
Corrosion and heat resistant conveyor belts.

B

Babcock & Wilcox Co. Tubular Products Div. 522
Tubular products and extrusions.

Baird Associates-Atomic Instrument Co. 1234
Direct reading spectrometer and spectrographic accessories.

Balcrank Inc. 521
Paint pumping equipment.

Baldwin-Lima-Hamilton Corp. 2104
SR-4 devices and equipment, testing equipment.

Balteau Electric Corp. 2622
Portable industrial X-ray units.

Banner Welder, Inc. 2769
Resistance welding equipment.

Barber-Colman Co., Wheelco Instruments Div. 1829
Recorders and controllers with combustion safeguards.

Barer Engineering & Machinery Co. Ltd. 2316
Lathes, drill presses, shapers and grinders.

Barker Engineering Co. 2830
Milling machines.

Bausch & Lomb Optical Co. 422
Metallographic equipment.

Bean & Co., Morris 920
Antioch process aluminum castings.

Bede Products Corp. 1101
Airless spray coating equipment.

Bendix Aviation Corp. 2123
Ultrasonic cleaning equipment and nonferrous castings.

Beryllium Corp. 1834
Beryllium copper alloys and pure beryllium.

Binks Mfg. Co. 2755
Paint spraying equipment.

Black Drill Co. Inc. 914
Drills for drilling hardened steel.

Blakeslee & Co., G. S. 1019
Cleaning equipment.

Boggis, Henry P. & Co. 2874
Tap grinders and tap-sharpening equipment.

Branson Ultrasonic Corp. 2145
Ultrasonic generators and thickness gages.

Brennen, Bucci & Weber Inc. 1732
Spot welder and portable arc welder.

Brinkmann & Co. Inc., C. A. 201
Metallographic and other laboratory equipment.

Brush Beryllium Co. 531
Beryllium and beryllium alloys.

Brush Electronics Co. 1726
Equipment for surface finish measurement and metal identification.

Buck Mfg. Co. 2546
Magnetic Drill Presses and clamping equipment.

Buck Tool Co. 1528
Compensating power chucks.

Budd Co. 1707
Gamma radiation sources for industrial radiography.

Buehler Ltd. 260
Equipment for preparation of metallographic specimens.

C

Cadmet Corporation 2667
Investment castings and Ampco wear strips.

Cam-Lok Div., Empire Products, Inc. 2520
Waterproof connectors and molding kits.

Cammann Mfg. Co. 1737
Metal disintegrators for machining hard metal.

Campbell Machine Div. 1816
Wet and dry abrasive cutting machines.

Carbide & Carbon Chemicals Co. 1608
Fire resistant hydraulic fluids, synthetic lubricants and metal-working fluids.

Carlingo Commodities Corp. 2107
Flame hardening equipment.

Carter Controls, Inc. 803
Air and hydraulic cylinders, valves and rotary actuators.

Center for Documentation and Communication Research 270
Literature searching machine.

Central Foundry Div., General Motors Corp. 2134
Iron and steel shell-molded castings.

Chicago Rivet & Machine Co. 2529
Tubular rivets and automatic rivet setting machines.

Chilton Co. 1402
Iron Age, Automotive Industries.

Cincinnati Sub-Zero Products Co. 2573
Production chilling machines.

Circo Equipment Co. 2101
Spray washer, vapor degreaser and ultrasonic metal cleaning equipment.

Cities Service Oil Co. 1229
Hydraulic oil, cutting oils, greases and heat prover.

Clementina Ltd. 2673
Blast cleaning equipment.

Cleveland Designers & Consultants, Inc. 2873

Cleveland Electric Illuminating Co. 911
Information on Cleveland and northeast Ohio.

Cleveland Grinding Machine Co. 337
Grinding equipment and accessories.

Cleveland Metal Abrasive Co. 1908
Cleaning and peening shot and grit.

Climax Molybdenum Co. 360
Molybdenum as an alloying element.

Cobalt Information Center 542
Metallurgical applications of cobalt.

Cold Metal Products Co. 1120
Precision cold rolled strip steel.

Collins Microflat Co. 939
Black granite surface plates.

Commander Mfg. Co. 736
Multiple drill and tapping heads.

Consolidated Vacuum Div., Consolidated Electrodynamics Corp. 1929
High-vacuum equipment.

Continental Drill Corp. 532

Continental Industrial Engineers, Inc. 2831
Heat treating equipment.

Cooper Metallurgical Associates 1033
Pure boron, boron alloys and borides.

Copperweld Steel Co. 311
Steel Div.
Leaded alloy and carbon steels.
Ohio Seamless Tube Div.
Seamless and welded tubing.

Crampton Mfg. Co. 1730

Crane Packing Co. 2617
Lapping machine and mechanical packings.

Curtiss-Wright Corp. 2032
Ultrasonic equipment; forgings, extrusions and castings.

D

Dake Corp. 2554
Arbor, hydraulic shop and guided platen presses.

Delta Power Tool Div. Rockwell Mfg. Co. 1916
Drill presses, grinders and lathe units.

DeSanno & Son, Inc., A. P. 1942
Abrasive cutoff machines and grinding wheels.

Detrex Chemical Industries, Inc. 1907
Cleaning and finishing compounds and equipment.

Detroit Testing Machine Co. 1806
Hardness, tensile and ductility testers.

De Walt, Inc. 2670
Radial arm metal cutting machinery; dynamic power brakes.

Dilley Mfg. Co. 810
Magnetic grip-shields.

Disston Div., Henry, H. K. Porter Co. Inc. 2731
Complete line of metalworking saws.

Diversey Corp. 1012
Cleaning and phosphatizing chemicals.

Dixon Sintaloy Inc. 2774
Powder metal parts.

Doehler-Jarvis Div., National Lead Co. 2111
Die castings.

Driver Co., Wilbur B. 248
Wrought special-purpose alloys.

Driver-Harris Co. 2411
Wrought and cast heat resistant alloys; thermocouples.

Drop Forging Assoc. 2530
Drop forgings.

DuBois Co., Inc. 2423
Cleaning and processing compounds.

Du Pont de Nemours & Co. Inc.
Electrochemical Dept. 1032
Degreasing process.
Explosives Dept. 1030
Industrial expansion rivets.

Dynamic Gear Co. 2871
Precision gears and gear assemblies.

E

Easco Products Div. Electro Arc Sales Co. 1204
Metal disintegrators and conversion units.

Eastman Kodak Co. 1002
New type AA industrial X-ray film.

East Shore Machine Products Co. 2560

Eclipse Fuel Engineering Co. 1724
Radiant heating gas burners and other equipment.

Electric Furnace Co. 1041
Industrial heat processing furnaces.

Electro Metallurgical Co. 1608
Titanium; Cr-Ni-Mn stainless steels.

Elox Corp. of Michigan 2131
Electron drills and precision electrical discharge machinery.

Enamelstrip Corp. 2628
Precoated steel in coils.

Engelberg Huller Co., Inc. 2746
New centerless grinder and wide sheet grinder.

Ercona Corp. 937
Zeiss Metallographic equipment.

Eriez Mfg. Co. 2716
Magnetic separators and automation units.

Exomet, Inc. 2571
Exothermic products and custom alloys.

F

Fabristeel Products, Inc. 1421
Clinch nuts and diversified fasteners.

Fawick Airflex Div., Fawick Corp. 1934
Punch press, cluches, brakes and controls.

Fenn Mfg. Co. 331
Combination two-high, four-high rolling mill.

Fenway Machine Co. Inc. 1204
Portable metal cutting tools.

Ferrotherm Co. 536

Forest City Foundries Co. 2856
Gray iron castings.

Fulton Foundry & Machine Co. 2753

G

Gas Appliance Service, Inc. 2837
Gas-fired heating equipment.

Gas Machinery Co. 2833
Industrial furnaces.

Gasway Corp. 2864
Roller coated materials.

General Alloys Co. 351
Heat resisting and stainless steel castings and fabrications.

General Electric Co.,
Apparatus Sales Div. 305
Metallurgical Products Dept. 2124
Carboloy cemented carbide and cemented oxide tool materials.
X-ray Dept. 1104
Industrial X-ray equipment.

General Riveters, Inc. 2616
Portable screwdriver and riveter.

General Ultrasonics Co. 2866
Ultrasonic generators.

Goodrich Co., B. F. 2535
Rivnuts.

Graham Machine Tool Co. 2403
Milling machines and surface grinders.

Graham Transmissions, Inc. 804
Variable speed transmissions for automated equipment.

Gray Co., Inc. 2618
Paint spray equipment.

Gries Industries, Inc. 550
Die castings and hardness testers.

Gulf Oil Corp. 1527
Oils and lubricants for the metal industry.

H

H & H Research Co. 715
Portable electric tools.

HPL Mfg. Co. 1240
Stampings.

Hacker & Co., Wm. J. 1709
Metallographic equipment.

Hamler Industries, Inc. 907
Ammonia distribution, steel fabrication and industrial X-ray Service.

Hammond Machinery Builders, Inc. 1250
New electrolytic chip-breaker grinder and electrolytic oscillating carbide tool grinder.

Harman Assoc., F. Ward 2718
Scale models and templates for plant layouts.

Harper Electric Furnace Corp. 724
Electric sintering and brazing furnaces.

Harris Calorific Co. 223

Harshaw Scientific Div., Harshaw Chemical Co. 2647
Metallurgical laboratory equipment.

Haynes Stellite Co. 1608
Heat and corrosion resistant alloys, investment castings, hard facing materials and cutting tools.

Heatbath Corp. 1506
Heat treating salt baths; finishing compounds.

Heil Process Equipment Corp. 2766

Heli-Coil Corp. 2415
Screw thread inserts.

Hevi Duty Electric Co. 209
Heat treating equipment.

High Vacuum Equipment Corp. 2702
Laboratory vacuum melting furnace.

High Voltage Engineering Corp. 720
X-ray generators and particle accelerators.

Hobart Brothers Co. 2541
Electric arc welders; welding supplies and equipment.

Holcroft & Co. 346
Industrial furnaces and gas generators.

Holden Co., A. F. 1415
Automatic carousel process conveyor.

Holger Andreasen, Inc. 537
Portable X-ray units for industrial radiography.

Holliday Co., R. L. 704

Hones Inc., Charles A. 2857
Industrial gas burners.

Houghton & Co., E. F. 1145
Compounds for drawing, cutting and surface treatment of metals.

Howard Foundry Co. 212
Aircraft and commercial quality castings.

Huck Mfg. Co. 2805
Bolts, blind rivets and driving tools.

I

Illinois Testing Laboratories, Inc. 1214
Temperature measuring and controlling instruments.

Industrial Heating 2765

Industrial Heating Equipment Co. 2561
Complete line of heat treating furnaces.

Industrial Press 1729
Machinery and engineering books.

Industrial Publishing Group 801

Industrial Tectonics, Inc. 2517
Special alloy bearings and balls.

Instron Engineering Corp. 2430
Testing equipment.

International Nickel Co., Inc. 402, 408
Nickel and nickel alloys; movie on "Mining for Nickel."

Invincible Vacuum Cleaner Mfg. Co. 2703
Industrial vacuum cleaners.

Ipsen Industries, Inc. 321
Endothermic generator with automatic ratio control; heat treating furnaces.

Ivy Co. 2008
Fatigue testing equipment.

J

Janney Cylinder Co. 2621
Centrifugal castings and machined products.

Jarrell-Ash Co. 1111
Spectrometers and spectrographic equipment.

Jergens Tool Specialty Co. 2572
Jig and fixture components.

Jerpbak-Bayless Co. 814
Thread grinding equipment.

Jiffy Disintegrators, Inc. 2761
Jiffy disintegrator machines for removing broken taps.

Johnson & Son, Inc., S. C. 1924
New water-soluble cutting fluid.

Jomac Inc. 2715
Industrial work gloves.

K

Kemp Mfg. Co., C. M. 2853
Industrial gas combustion equipment.

Kennametal Inc. 1824
Tungsten and titanium carbide products.

Kerns Co., L. R. 2547
Drawing, cutting, grinding and forging compounds.

King Tester Corp. 253
Brinell testing machines and microscopes.

Kinney Mfg. Div., New York Air Brake Co. 728
Vacuum equipment.

Kirkhof Mfg. Co. 2860

Knight Models, Inc. 2756
Three-dimensional model of metalworking plant.

Kolcast Industries, Inc. 1119
Investment castings.

Kolene Corp. 1330
Salt bath cleaning processes.

Krouse Testing Machine, Inc. 2512

Kux Machine Co. 1420
Diecasting machine and powdered metal press.

L

Laboratory Equipment Corp. 2655
New induction furnaces; carbon and sulphur analyzers.

Lake Shore, Inc. 2542
Surface plates, base plates, engine jacks and stands.

Lakeside Steel Improvement Co. 306
Heat treating and testing service.

Lee Co., K. O. 2044
Grinding machines and accessories.

Leeds & Northrup Co. 1129
Steam Homo furnace; gas analysis and temperature control demonstrations.

Leitz, Inc., E. 702
Dilatometer-heating microscope and bench microscopes.

Lempco Industrial, Inc. 1236
Grinders and die sets.

Lepel High Frequency Laboratories, Inc. 2211
Induction heating equipment.

Lewis Machine Co. 2002
Wire straightening and cutting machine.

Lincoln Electric Co. 440
Welding equipment and supplies.

Lindberg Engineering Co. 431
Heat treating equipment.

Linde Air Products Co. 1608
Heliarc cutting and spot welding, flameplating, oxy-acetylene welding and cutting.

Loftus Engineering Corp. 2650
Industrial furnaces.

Logansport Machine Co., Inc. 2207
Special air and hydraulic equipment.

Los Angeles Dept. of Water & Power 2329
Industrial opportunities in the San Fernando Valley.

Lufkin Rule Co. 1721
Precision tools, measuring tapes and rules.

Lynchburg Foundry Co. 1519
Ductile and gray iron castings.

M

Machlett Laboratories, Inc. 2438
Electronic tubes for X-ray and induction heating equipment.

Magnaflux Corp. 231
New Magnaflux and Zyglo inspection materials.

Magnethermic Corp. 2336
Aluminum extrusion press with Magnethermic induction billet heater.

Magnetic Analysis Corp. 1235
Magnetic analysis equipment.

Malayan Tin Bureau 2410
Applications of tin in industry.

Manganese Steel Co. 2728
Forged manganese steel screens and plates.

Manufacturers Processing Co. 2821
Degreasing equipment.

Marquette Metal Products Div. 2032
Precision spring clutches.

Martindale Electric Co. 1212
Metal-cutting circular saws, rotary files and electrical equipment.

M. B. I. Export and Import Ltd. 2312
Horizontal optical jig borer and special small tools.

McGuire, Thos. B. 907

Metal Carbides Corp. 2024
Tungsten carbide cutting tools and wear resistant parts.

Metal Progress 240

Metal Removal Co. 2033
All-purpose abrasive.

Metallizing Co. of America 506
Metallizing equipment.

Metallizing Engineering Co., Inc. 2233
Thermospray equipment for hard surfacing.

Metallurgical, Inc. 818
Heat treating service.

Metalwash Machinery Corp. 2847
Metal cleaning equipment.

Met-L-Check Co. 704
Met-L-Chek flaw-finder and dye penetrant.

Micrometrical Mfg. Co. 432
Profilometer and other surface control equipment.

Miller Fluid Power Div. 1623
Air and hydraulic cylinders.

Minneapolis-Honeywell Regulator Co., Industrial Div. 312
Saturable reactor and process control systems.

Modernair Corp. 2609
Fluid power devices.

Mohawk Tools, Inc. 716
Subland tools, also size-optional drills.

N

Naresco Equipment Corp. 2108
New 12-lb. vacuum induction furnace and other vacuum equipment.

National Carbon Co. 1608
Carbon and graphite products.

National Cored Forgings Co., Inc. 445
Cored and solid nonferrous forgings.

National Malleable and Steel Castings Co. 1703
Malleable iron and steel castings.

National Precision Casting Corp. 2828
Ferrous and nonferrous investment castings.

National Spectrographic Laboratories, Inc. 2830
New hydrogen and carbon analyzer.

National-Standard Co. 2608
Specialty steel wires and wire cloth.

Nelson Stud Welding Div., Gregory Industries, Inc. 1930
Stud welding equipment.

New Hermes Engraving Machine Corp. 2510
Pantograph engraving machines.

Nicholas Equipment Co. 2424
Polishing and grinding machines.

Nichols Co., R. W. 1323
Air control valves, index tables and presses and automatic drill heads.

North American Mfg. Co. 1512
Gas burners and turbo blowers.

North American Philips Co., Inc. 2635
X-ray spectrographic equipment.

North American Viking Drill Co. 532
High speed and carbon steel tap and twist drill sets.

Norton Co. 2414, 2657

O

Oakite Products, Inc. 941
Materials and equipment for cleaning, finishing, machining and grinding.

Ohio Hydro Deburring Co. 2564
Barrel finishing equipment.

Ohio Metal Working Products Co. 505

Ohio Nut & Bolt Co. 2760
Ohio weld fasteners.

Ohio Steel Foundry Co. 910
Heat and corrosion resistant alloy castings.

Olsen Testing Machine Co., Tinius 1137
Testing machines.

O'Neil-Irwin Mfg. Co. 1410
Hand and power operated benders, brakes and shears.

Osborn Mfg. Co. 2116
Brushamatic machines and industrial brushes.

Overbeke-Kain Co. 2620
Portable workbench and tool carrier.

P

Pangborn Corp. 1901
Blast-cleaning equipment.

Pantex Mfg. Corp. 2666
Steam jet cleaner and steam superheater.

Park Chemical Co. 1515
Heat treating materials, protective coatings and cutting and grinding fluids.

Patterson Machine Co., Geo. C. 2442
Wire straightening and cutoff machines.

Pedrick Tool & Machine Co. 2456
Bending machines.

Peerless Electric Co. 706
Equipment for detection and correction of thermocouple circuit failures.

Penton Publishing Co. 1425
Steel, Machine Design, Foundry, Automation and *New Equipment Digest.*

Phillips Mfg. Co. 1320
Metal cleaning equipment.

Phoenix Products Co. 2567
Spun metal parts and welding electrode oven.

Picker X-ray Corp. 2557
Industrial X-ray equipment.

Plastic Metals Div., National-U.S. Radiator Corp. 2515
Metal powders.

Pneuma-Serve Inc. 1110
Fastener feeding unit.

Portomag, Inc. 2708
Portable magnetic drill press.

Precision Castings Co., Inc. 1038
Die castings.

Precision Metalsmiths, Inc. 1830
Ferrous and nonferrous investment castings.

Precision Scientific Co. 2568
Metallographic laboratory equipment.

Precision Shapes, Inc. 510
Mill-length metal shapes produced by continuous milling.

Precision Steel Warehouse, Inc. 2140
Precision brand steel and copper alloys.

Precision Tube Co., Inc. 2832
Seamless nonferrous tubing.

Pressco Casting & Mfg. Corp. 2615
Cast nonferrous gears.

Production Machine Co. 1809
Centerless grinding machine and surfacing machines.

Pyrofax Gas Corp. 1608
Pyrofax LP gas for industrial purposes.

Pyrometer Instrument Co., Inc. 1037
Surface, radiation, immersion and indicating pyrometers.

R

Radiator Specialty Co. 2867
Rubber and plastic products.

Ramco Equipment Corp. 2564
Vapor degreasers and power spray washers.

Ransburg Electro-Coating Corp. 1714
Electrostatic paint spraying equipment.

Ransohoff, Inc. 2734
Automatic ultrasonic cleaning machine.

Raytheon Mfg. Co. 2848
Electronic welding and impact grinding equipment.

Reeves Div., Reid-Avery Co. 1130, 2861
Welding supplies.

Reliance Electric & Engineering Co. 1130

Renton & Co., R. W. 2852
Cleaning and finishing equipment.

Richards Co., J. A. 1230
Multiform benders.

Riehle Testing Machines Div., American Machine & Metals, Inc. 241
Testing machines.

Rodgers Hydraulic, Inc. 2722
Platen press.

Rotherm Engineering Co. 711
Expansion joints, revolving joints and piping compensators.

Ryerson & Son, Inc., Joseph T. 405
New E-Z-Cut (leaded) steel plate and flamecut irregular shapes.

S

S-P Mfg. Corp. 2850
Air and hydraulic cylinders.

Scherr Optical Tools, Inc., Geo. 710
Microscopes and inspection equipment.

Schrader's Son Div., A. 1812
Pneumatic valves and cylinders.

Sciaky Bros. Inc. 2206
Resistance welding equipment and controls.

Scientific Electric 2502
Paint spraying equipment.

Scott Paper Co. 703
Towels and industrial wipers.

Scovill Mfg. Co., Inc. 1812
Copper alloys.

Sealol Corp. 1505
Fluid transfers and adapters for high-pressure coolant application.

Sentry Co. 1203
High speed steel hardening furnace.

Service Diamond Tool Co. 1735
Hardness testing machines and accessories.

Sheldon Machine Co., Inc. 1723
Variable speed drive lathe with automatic speed selector.

Shell Oil Co. 1316
Cutting and quenching oils.

Sieburg Industries, Inc. 2770
Equipment for machining tensile specimens.

Sinclair Refining Co. 2646
Quenching, grinding and soluble oils.

Sintox Corp. of America 1823
Cutting tools and holders.

Skil Corp. 2239
Portable power tools.

Skinner Chuck Co. 2601
Hand chucks, machine vises and power chucking equipment.

Socony Mobil Oil Co., Inc. 1840
Cutting oils and rust preventatives.

Southco Div., South Chester Corp. 1017
Drive rivets and fasteners.

Special Libraries Assoc. 370
Technical and reference books.

Spee-Flo Co. 2772
Painting equipment.

Spencer Scientific Instruments 1136

Spencer Turbine Co. 2749
Portable vacuum cleaners, turbocompressors and pneumatic conveying systems.

Sperry Products, Inc. 1428
Ultrasonic inspection equipment.

Spitfire Tool Co. 2550
Lapping machines.

Standard Electric Tool Co. 1047
Precision spindles and variable speed grinders.

Standard Oil Co. (Ohio) 2307
Petroleum products.

Standard Parts Co. 2671

Stanley Electric Tools Div. 1741
Drills, sanders and grinders.

Starrett Co., L. S. 919
Precision instruments and hand tools.

Steel City Testing Machines, Inc. 1324
Machines to test physical properties of metals.

Stimpson Co., Inc., Edwin B. 411
Rivets, stampings and screw machine parts.

Stokes Machine Co., F. J. 1520
Powder metal press; vacuum equipment.

Struers Chemical Laboratory 815

Sunbeam Corp., Industrial Furnace Div. 942
Gas carburizing furnace and atmosphere quench equipment.

Superior Foundry, Inc. 1207

Superior Pneumatic & Mfg., Inc. 2819
Air hammers and pneumatic accessories.

Superior Tube Co. 1220
Small diameter metal tubing.

Supreme Products, Inc. 2721

Surface Combustion Corp. 421
Heat treating furnaces and steel mill equipment.

Swift Industrial Chemical Co. 836
Heat treating and finishing chemicals.

T

Taylor Instrument Co. 2817
Temperature and pressure indicators and controllers.

Technic, Inc. 811
Plating equipment and supplies.

Tech-Pacific Corp. 1730
Metalworking equipment.

Telenews Productions Inc. 801
Industrial Publishing Group, *Industry & Welding*.

Tempil Corp. 929
Temperature indicating materials.

Texas Co. 1602
Cutting and drawing compounds.

Thomas Publishing Co. 2869
Thomas' Register of American Manufacturers Industrial Equipment News.

Thomson Electric Welder Co. 1751
Flash welder equipped with synchro-shear.

Thor Power Tool Co. 2723
Portable air and electric tools.

Tickle Engineering Works, Inc., Arthur 2326
Alumicoat and Alumibond process.

Timken Roller Bearing Co., Steel & Tube Div. 1051
Alloy steel, graphitic tool steels and Hollowbar tool steel.

Tinnerman Products, Inc. 1029
Standard and special engineered fasteners.

Titanium Alloy Mfg. Div., National Lead Co. 2111
Zirconium and titanium alloys and compounds.

Titanium Metals Corp. of America 1241
New titanium alloys.

Tocco Div., Ohio Crankshaft Co. 2212
Automated induction heating equipment.

Torit Mfg. Co. 935
Torit dust collectors.

Torsion Balance Co. 1740
Combination hardness tester, microhardness tester, analytical and industrial balances.

Trerice Co., H. O. 816
Thermometers, temperature and pressure regulators.

Tubular Micrometer Co. 1009
Precision measuring instruments.

Turco Products, Inc. 2234
Aluminum conversion coating, phosphate coatings and chemical milling supplies.

U

Uddeholm Co. of America, Inc. 815
Toolsteel and laboratory equipment.

Union Carbide & Carbon Corp. 1608
See Linde Air Products Co., Carbide and Carbon Chemicals Co., Electro Metallurgical Co., Pyrofax Gas Corp., National Carbon Co. and Haynes Stellite Co.

Union Mfg. Co. 2629
Lathe chucks, die sets and accessories.

United Scientific Co. 2661
Microscopes and metallographic equipment.

United Shoe Machinery Corp. 1835
Blind rivets, eyelets and eyelet machinery.

United Wire & Supply Corp. 554
Brazing alloys and fluxes; wire and seamless drawn tubing.

Universal Castings Corp. 2754
Nonferrous castings.

Universal Tumbling Supply Co. 2570
Precision tumbling materials.

Uniworld Research Corp. of America 809
Age hardenable, corrosion and heat resistant stainless steels; corrosion resistant cast irons; low-temperature braze welding.

Upton Electric Furnace Co. 1509
Graphite electrode salt bath furnace.

U.S. Automatic Corp. 1101

U.S. Electrical Motors, Inc. 2230
Variable speed motors.

U.S. Gypsum Co. 830
Cements, plasters for precision castings and epoxy resin for industrial tooling.

U.S. Rubber Co. 2823
Vinyl sheeting laminated to steel and aluminum.

V

Vaco Products Co. 2675
Miscellaneous hand tools.

Vacu-Blast Co., Inc. 2719
Blast-cleaning equipment.

Vanadium Corp. of America 343
Ferro-alloys, metals and chemicals.

Vandersee Corp. 2408
Metallizing machines and accessories.

Viking Drill & Tool Co. 532

W

Waldes Kohinoor, Inc. 2240
Retaining rings, pliers, assembly and accessory tools.

Wales-Strippit Corp. 2405
Sheet metal fabricator.

Wallace Supplies Mfg. Co. 2491
Duplicating bender and combination cutting and deburring machine.

Watson-Stillman Press Div., Farrel-Birmingham Co., Inc. 2777

Waukee Engineering Co., Inc. 2508
Flowmeters, gas-air mixers and industrial washing machines.

Weatherhead Co. 2029
Industrial fittings and hose.

Wells Mfg. Corp. 1912
Metal cutting band saws.

Westinghouse Electric Corp. 1711
Vacuum melting furnace; welders; R F heating; fluoroscopic testing; alloys; motors and controls.

Weston Electrical Instrument Corp. 2737
Electrical recording and controlling instruments.

Wheelabrator Corp. 2580
New Wheelabrator super-tumblast.

Whistler & Sons, Inc., S. B. 2014
Magnetic and universal adjustable perforating equipment.

Wilson, Inc., K. R. 2407

Wilson Mechanical Instrument Div. 1211
Rockwell and Tukon hardness testers.

Wilton Tool Mfg. Co., Inc. 808
Vises and work positioners.

Y

Yale & Towne Mfg. Co. 915
Powder metal parts.

Z

Zaco Laboratories 1219
Colored paint for metal identification.

Zagar Tool Inc. 2752
Collets and drilling equipment.

Zeiss, Inc., Carl 2522
Microscopes and metallographic equipment.

Economic Atomic Power Depends on Materials of Construction

*By JOHN H. FRYE, JR. and JAMES L. GREGG**

If metallurgists, ceramic engineers and chemists can produce the necessary constructional materials and low-cost uranium refining methods, a breeder reactor using uranium isotope 233 and a thorium blanket can generate heat at costs comparable to steam boilers using coal. (T25, U, Th, Al, Zr)

IT HAS BEEN clear for some time that electrical power can be produced in nuclear reactors of several different designs. There is not space to discuss all of these possibilities in this article; merely to list them taxes the limits of the data sheet, p. 96-B. Furthermore, many of the features are still "classified" information. Suffice it to say that, although the production of nuclear power is technically feasible and sizable power plants are under construction in England, the main problem is one of reducing costs to the point where the power is economically competitive with existing sources of energy. Even though this means that the Englishman or the Alaskan will have a different view of the proposition from the Pennsylvanian or the Texan, since the economics (principally cost and availability of adequate coal or fuel oil *at the site*) differ markedly at various places on the earth, we will attempt to show how the major problems lie in the field of materials, and are therefore of particular interest to the metallurgist. We hope this article will give the reader some insight into the materials and materials-handling costs involved in producing economical power from uranium. We shall say nothing about capital and operating costs, important though they are.

Fortunately for our purpose, there is one reactor that has operated reliably since early in 1952, and for which the costs are known in some detail and which can be discussed rather fully without violating security requirements. This reactor is the Materials Testing Reactor in Idaho, the so-called M.T.R. It operates at a low temperature – below the boiling point of water – and is used for testing purposes and not for power production. Nevertheless, it could be converted to power production without any major change in the cost of the raw materials or for their fabrication and reprocessing. Therefore, a study of this installation gives real insight into the problem of nuclear power.

Furthermore, reactors of this type are of great importance because they are concentrated sources of energy. For example, in one cubic yard of space one can easily produce 100 million watts of heat (roughly 130,000 hp. continuously, at 100% conversion into power) and continue to do so for two months without replenishing the uranium being fissioned! When the fuel must be replaced, the total weight of uranium and container is of the order of a ton; whereas, if coal were used, several thousand tons would be required. Thus, such reactors are important for power production in remote and

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inaccessible regions and for the propulsion of various large vehicles and sea-going vessels.

The M.T.R. is normally operated at a power level of 40,000 kw.* Fuel is the uranium isotope having a mass of 235, normally designated U^{235}. For each gram of fuel fissioned, approximately one megawatt-day or 2.4×10^4 kw-hr. of energy in the form of heat is released. The reactor, therefore, "burns" approximately 40 g. of U^{235} per day.

In preparing the fuel, uranium is alloyed with about five times its weight of aluminum, poured into small ingot molds and rolled down to 0.25-in. plates. Small square wafers are then surrounded on all sides by aluminum, and this whole "picture-frame" assembly rolled into slightly dished sheets 0.06 in. thick, 3 in. wide, and 26 in. long. These are assembled and brazed into the fuel unit shown in the photograph. Each end is closed by a hollow aluminum casting which can enter corresponding holes in "tube sheets" at each end, thus accurately spacing each rectangular unit so it clears its neighbors by about the same distance as that between the curved plates. Heat is extracted from these units by pumping water through them. If they were clad with some metal with better high-temperature properties than aluminum, such as steel or a nickel-base alloy, it would be possible to operate the M.T.R. at temperatures high enough to produce useful power, but for developing the argument we will assume that aluminum can be used at such higher temperatures. If we analyze the costs of the materials involved in power production, these costs should not be altered drastically by the use of steel in the place of aluminum, and the results would give a fairly accurate picture of the cost of producing power from the fissioning of U^{235}.

Elements of Cost

The uranium metal used as fuel in the M.T.R. is "highly enriched", meaning that it contains at least 90% of the isotope U^{235}. (Natural uranium, as is well known, contains 99.3% U^{238} and only 0.7% U^{235}.) While the actual cost of U^{235} in this enriched uranium cannot be ascertained, it has been variously estimated at $15 to $30 per gram. The cost of fuel per kw-hr. of heat would then be between 0.6 and 1.25 mills. If thermal energy can be converted to electric energy at an efficiency of 25%, the fuel costs would be between 2.5 and 5 mills per kw-hr. of electricity. In comparison, the cost of coal burned in a steam plant in this country will range from 2 to 5 mills per kw-hr. of electricity produced, depending on the cost of the fuel delivered to the plant and on the efficiency of converting thermal to electric energy in that particular plant.

In addition to the actual cost of fuel burned, there are other costs in connection with reactors that are not encountered in coal-burning steam plants. In order to use the uranium in the M.T.R., it is alloyed with aluminum, rolled into plates, and then clad with aluminum. Eighteen of these plates are then brazed to side plates to form the fuel element shown in the photograph. Each fuel element contains approximately 200 g. of U^{235} and the cost of fabricating a single fuel element has been estimated to be between $300 and

Fuel Element Devised at Oak Ridge National Laboratory for the Materials Testing Reactor in Idaho. It consists of parallel plates – 0.020-in. sheets of uranium-aluminum alloy clad with 0.015 in. of pure aluminum. The uranium has at least 90% of the fissionable isotope U^{235}. This type of fuel element has been used in a dozen or more test reactors constructed since 1952

*That is, produces 40 million joules of heat per sec., equivalent (again at 100% conversion into power) to 53,500 hp.

$600 or $1.50 and $3.00 per g. of uranium. When only 25% of the U^{235} has fissioned ("burned"), the fuel element must be replaced.* The fabrication cost per gram of uranium actually consumed is, therefore, four times the values given above, or between $6.00 and $12.00 per g. At an efficiency of 25%, this fabrication cost would amount to between 1 and 2 mills per kw-hr. of electricity.

The remaining uranium in each element must then be separated from its fission products and recovered for reuse. This is usually done by dissolving the entire assembly in dilute nitric acid, and then separating chemically the aluminum, fission products and uranium. The fuel element from the reactor is highly radioactive, and the element as well as the solution resulting from its dissolution must be kept behind heavy shields. The handling of highly radioactive materials is inherently expensive, due to the necessary equipment for remote control and protection of personnel, and the cost of chemical processing may be assumed to be in the range of $1.00 to $5.00 per g. of uranium processed. As 3 g. of uranium must be processed for each gram burned, the cost per gram of uranium burned will be between $3.00 and $15. Again assuming an efficiency of conversion, heat to power, of 25%, the processing cost of recovery would be between 0.5 and 2.5 mills per kw-hr. of electricity.

The real fuel costs in mills per kw-hr. of electricity generated from a plant like the M.T.R. might then be assumed to be within the range shown below. In addition to these costs, there is the cost of disposing of radioactive wastes and the inventory costs on fuel. Together, these might add from 0.1 to 0.3 mill per kw-hr. of electricity.

	Low	High
Cost of U^{235} burned	2.5 mills	5.0 mills
Fabrication	1.0	2.0
Chemical processing	0.5	2.5
Total	4.0 mills	9.5 mills
Coal	2 mills	5 mills

Costs in the range indicated may be allowable for military reactors and for reactors used for research and testing, but are too high to manufacture power in America, where we still have vast reserves of unmined coal. Fortunately, there are definite possibilities of lowering the real cost of fuel to a value that will make it at least competitive with our fossil fuels.

*It has been reported that the elements are now operated to a burnup of 40%.

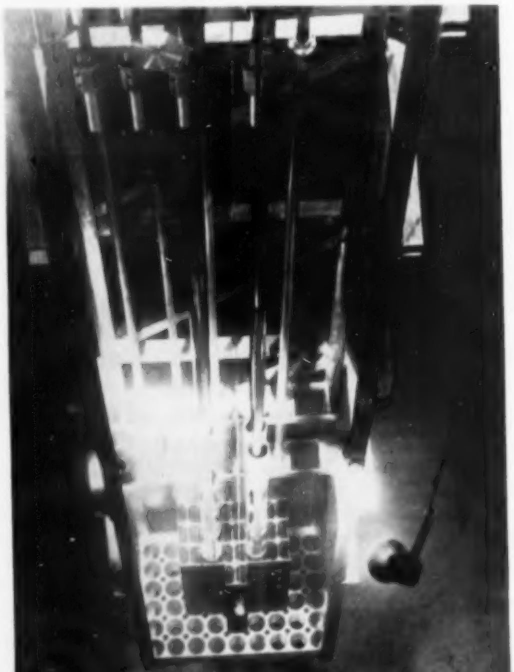
Thorium for Breeding

One possibility is to use the excess neutrons which form during fissioning (that is to say, the excess over those required to perpetuate the chain reaction and those unavoidably lost, strayed or stolen) to produce new fissionable atoms, thus having a reactor that *makes* fuel about as fast as it burns fuel. Certain types of reactors produce as many new fissionable atoms as are consumed. It is common to speak of this as "breeding".

In the M.T.R., each ten atoms of U^{235} consumed produces 21 neutrons, on the average. If we used U^{233} (that is, the uranium isotope of mass 233) instead of U^{235}, the same energy would be released per fission, and we would obtain 23 neutrons for every ten atoms of U^{233} consumed. In either case ten of the neutrons must be used to fission the next ten atoms of U^{233} or U^{235} in order to keep the reactor operating. Some of the surplus could be used to produce U^{233} from thorium. Let us see how this might be done.

When an atom of thorium captures a neutron, it transforms into an atom of U^{233}. Thus, if we could design a reactor using U^{233} so that ten out of each 13 excess neutrons were captured by ten thorium atoms, we would produce in the thorium blanket or shield a new atom of U^{233}

"Swimming Pool" Research Reactor, Such as This One at Penn State University, Uses Open-Ended Fuel Elements of Plate Type, and Water as a Coolant and Radiation Barrier



for each atom of U^{233} consumed in the fuel element. Let us assume that we are able to design such a reactor.

The cost of power would then be greatly reduced, as can be seen by the following table:

	Low	High
Cost of U^{233} burned	0.2 mills	0.8 mills
Fabrication	1.0	2.0
Chemical processing	0.5	2.5
Total	1.7 mills	5.3 mills
Coal	2 mills	5 mills

The cost of fabricating and of chemically processing the fuel units should be roughly the same for either U^{233} or U^{235}. However, the cost of burning U^{233} is much less than that for burning U^{235}. This represents the sum of the original cost of the thorium metal converted plus the cost of removing the U^{233} from the mass of unchanged thorium in which it is produced. The first is negligible; only the second need be considered.

Here we will assume that the cost of chemically removing U^{233} from thorium is the same as for removing U^{235} from the fabricated fuel elements. We will also assume that the thorium should be processed when the uranium content reaches 0.2 to 1%. On this basis, U^{233} will range in cost from $1.00 to $5.00 per g. as against $15.00 to $30.00 per g. of U^{235}.

The tabulation above shows that the total estimated cost of power in a breeder reactor should range from 1.7 to 5.3 mills per kw-hr., and this compares favorably with costs of 2 to 5 mills in a coal-fired steam plant. The nuclear fuel costs are necessarily rough approximations, but they do make one thing quite clear, namely:

The cost of fuel is almost entirely dependent on the cost of metallurgical fabrication and chemical processing.

If and when the metallurgists and chemists can reduce their costs to very low levels, nuclear fuel will be in a position to replace coal for the production of electrical power, even in the United States, where we have comparatively cheap coal.

A Practicable Power Plant

The figures presented in the second table indicate that, given a thermal efficiency of 25% and a breeding system, nuclear power should be competitive with coal power in the United States. Aluminum is suitable to contain the uranium and fission products in a breeding reactor because it captures very few neutrons, but it must be used at such low temperatures that the efficiency of the conversion of heat to power would be intolerably low. The only metal which does not capture so many neutrons that a breeding system could not properly operate and which can be used at reasonably high temperatures is zirconium. Thus, if zirconium were substituted for aluminum in the well-tried elements of plate form, it would be possible to have a breeding reactor which can operate and produce power in quantity. We shall, therefore, consider the economics of such a reactor.

A system which has been demonstrated to be practicable uses pressurized water as a heat-transfer medium. In this system, water is heated to the neighborhood of 600° F. by solid fuel elements in the core of the reactor. This hot water goes to a heat exchanger where it generates steam. This steam, in a secondary circuit, drives a conventional turbine.

The first disadvantage of this system is that it cannot operate at as high a thermal efficiency as a conventional power plant that uses steam at 1100° F. This automatically increases the cost of the electricity since, for a given cost of heat, the cost of electricity varies as the reciprocal of the efficiency of conversion of heat to electricity. If the costs of fabrication and of chemical processing can be kept sufficiently low, however, the decreased efficiency will not be the ruling factor.

We return again to the second table to discuss these costs. The cost of U^{233} is not altered by substituting zirconium for aluminum. The cost of fabrication will definitely be increased, because zirconium is much more expensive than aluminum and is much more costly to fabricate. Although actual figures cannot be given, it is probably impossible for such a reactor to compete with cheap coal today.

There are some power reactors now in operation, others in course of construction, and a number of reactor systems under investigation in this country, not only by governmental agencies but by private industry. (See the data sheet, p. 96-B.) These systems and the materials problems involved in them have recently been discussed in some detail in a special report on nuclear metallurgy by the Institute of Metals Division of the American Institute of Mining, Metallurgical and Petroleum Engineers. Suffice it to say that in all of these schemes the limiting factors lie in the fields of chemistry, ceramics and metallurgy. Not only is it important to keep down the chemical and fabrication costs, but in some systems there are the added factors of

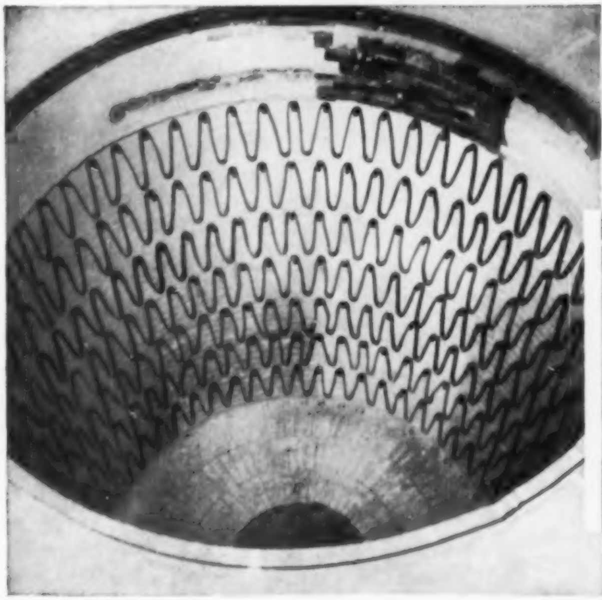
durability and reliability of materials under existing conditions of corrosion and radiation. In certain systems which appear very attractive on paper, the localized temperatures and radiation intensities are beyond the capacity of available metals fabricated in conventional ways, and their practicability will depend upon whether proper ceramic or ceramic-metal compositions can be formulated and fabricated. Even these factors can be expressed in economic terms, since they either shorten the life of expensive equipment or require more frequent chemical and metallurgical processing.

Package Power Reactor

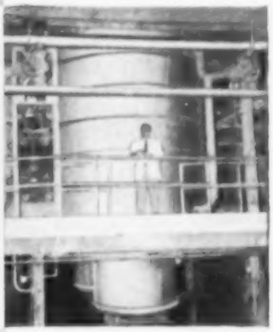
The kind of reactor discussed in this article – a reactor using solid fuel elements which transfer the heat they generate to surrounding water – is quite well suited to power production in remote locations and to the propulsion of large vehicles. It is, therefore, an important kind of reactor and well worth study. In addition, certain conclusions, which can be drawn about this class of reactors, are generally applicable. They are:

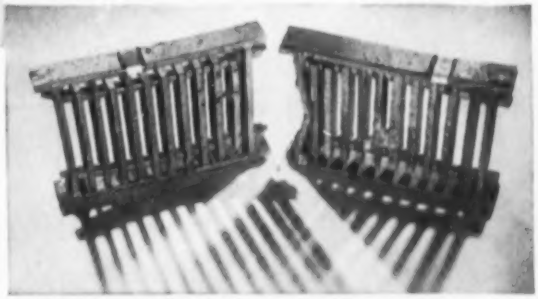
1. Electricity can be produced reliably by nuclear reactors.
2. The question of how extensively and how soon nuclear power will replace coal power is an economic one.
3. In much, if not all, of the United States it is cheaper to use coal than enriched U^{235} as a fuel, and there is no reason to expect this situation to change in the near future.
4. It is not necessary to use U^{235} as a fuel if a breeding reactor is used. For example, U^{233} can be burned in the core and replaced by U^{233} bred in a surrounding blanket of thorium.
5. Such a reactor can produce electricity more cheaply than a coal-fired plant if costs of metallurgical fabrication and chemical processing can be kept sufficiently low.
6. Thus, the future of nuclear power in this country rests primarily in the hands of metallurgists, ceramic engineers and chemists.

Design Study of "Package" Power Reactor for U.S. Army Made by Oak Ridge National Laboratory. Reactor and controls in near corner, heat interchanger below floor slabs at center, turbo-generator set above, and "cooling tower" at left



This Vacuum Retort was used at Pacific Northwest Alloys, Inc., Spokane, Washington, for producing low carbon ferrochrome. Temperature was held at over 2175°F. for several days during production cycles. Atmosphere, primarily carbon monoxide, contained some metal vapor at an absolute pressure that varied from one inch to 100 microns of mercury. During 10 production runs, INCO Engineers tested a variety of heat-resistant alloys in this furnace.





Which Alloy Will Perform Best? Racks like these, often help to determine exactly the right metal for a specific application. Various cast and wrought alloys were assembled on the two racks, and placed in the retort, shown above, for 10 production cycles. One of the specimens under test was practically immune to corrosion with a loss of only .006 ipy. Average corrosion rates in inches penetration per year for the other specimens ranged from .015 to .153 inches.

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Power Reactor Programs in the U. S.

Line	Reactor and Owner (a)		Location	Output; Kw. Heat	Output; Kw. Power	Fuel Amount	Fuel Enrichment
	Major Experimental Power Reactors in the Atomic Energy Commission's Program						
A	EBR-1	Argonne	Idaho	1400	150	48 kg. U	90 %±
B	EBR-2	Argonne	Idaho	62,500	17,500	90 kg. Pu + 150 kg. U	45 %
C	HRE-1	ORNL	Oak Ridge	1000	150	3 kg. U	90 %±
D	HRE-2	ORNL	Oak Ridge	Up to 10,000	300	4 kg. U	90 %±
E	BORAX-3	Argonne	Idaho	15,000	2400	15 kg. U	90 %±
F	EBWR	Argonne	Argonne	20,000	5000	4500 kg. U	1.4%
G	SRE	N.A.A., Inc.	Sta. Susanna	20,000	7500	2100 kg. U	2.9%
H	LAPRE-1	Los Alamos	Los Alamos	2000		8.4 kg. U	90 %±
I	LAPRE-2	Los Alamos	Los Alamos	1300		7.7 kg. U	90 %±
J	LAMPRE	Los Alamos	Los Alamos	1000		Molten plutonium alloy	
K	OMRE	N.A.A., Inc.	Idaho	16,000		20 kg. U	90 %±
	Prototype Power Plants to Be Financed Primarily by American Industry						
L	Westinghouse and Duquesne Power Co.		Shippingport	235,000	100,000±	12 tons natural U	45 kg. U^{235}
M	Consumers Public Power District		Nebraska	250,000	75,000	24,600 kg. U	1.8%
N	Yankee Atomic Electric Co.		Massachusetts	500,000	134,000	25,500 kg. U	2.7%
O	Detroit Edison and Associates		Michigan	300,000	100,000	2100 kg. U	20 %
P	Commonwealth Edison and Associates		Illinois	680,000	180,000	68,000 kg. U	1.1%
Q	Consolidated Edison		New York	500,000	250,000 (f)	275 kg. U	90 %±
R	Westinghouse and Penn Power & Light		Pennsylvania		150,000	Homogeneous reactor	
	"Second Round" in the Power Demonstration Program						
S	Chugach Electric Assoc., Alaska		Anchorage	40,000	10,000	10,000 kg. U	2 %±
T	Wolverine Electric Cooperative		Michigan	15,700	10,000 (i)	12 kg. U	90 %±
U	University of Florida		Gainesville	10,000	2000		35 %±
V	City of Orlando, Florida		Orlando		<40,000	67 kg. U	90 %±
W	Rural Cooperative Power Assoc.		Minnesota	58,000	22,000	10,000 kg. natural U	1.2%
X	City of Piqua, Ohio		Piqua	45,500	12,500	6300 kg. U	3 %
Y	City of Holyoke, Mass.		Holyoke	44,000	15,000	70 kg. U	5 %

Line	Moderator	Coolant Nature	Coolant Temp° F.	Coolant Pressure (b)	Costs Reactor (c)	Costs Total Plant	Costs Per Kw.	Completion Date
	Major Experimental Power Reactors in the Atomic Energy Commission's Program							
A	None	NaK	600	100	2,700,000	3,300,000 (d)		1951
B	None	Na	1000	100	15,300,000	39,600,000 (d)		1959
C	H_2O	Fuel solution	480	1000	1,100,000	9,700,000 (d)		1953
D	D_2O	Fuel solution	570	2000	1,800,000	38,800,000 (d)		1956
E	H_2O	H_2O	420	300	600,000			1955
F	H_2O	H_2O	490	600	2,600,000	9,700,000 (d)		1956
G	Graphite	Na	960	300	4,900,000	13,400,000 (d)		1957
H	H_2O	Fuel solution	800	3900±	700,000	2,200,000 (d)		1956
I	H_2O	Fuel solution	600	800±	100,000	280,000 (d)		1956
J	None	NaK				3,000,000 (d)		1959
K	Diphenyl	Diphenyl	530	300	875,000	1,800,000 (d)		1957
	Prototype Power Plants to Be Financed Primarily by American Industry							
L	H_2O	H_2O	540	2000	37,700,000	47,700,000	750±	1957
M	Graphite	Na	925	300	13,500,000	24,300,000	320	1959
N	H_2O	H_2O	400	900	19,300,000	26,000,000	195	1960
O	None (e)	Na	800	<200	45,000,000	54,000,000	540	1960
P	H_2O	H_2O	480	600	34,200,000	45,000,000	250	1960
Q	H_2O (g)	H_2O	500	1500		55,000,000	230	1960
R		Fuel solution			Privately financed			1962
	"Second Round" in the Power Demonstration Program							
S	D_2O	Na	950	1 atm.	5,500,000 (h)	7,350,000	735	1961
T	D_2O	Fuel solution	570	2000	2,500,000	3,575,000	357	1959
U	H_2O	H_2O	450	1200	1,400,000	1,600,000	800	1959
V	Graphite (j)	Molten Bi-U alloy			12,500,000	20,500,000	510 to 820	1960
W	H_2O	H_2O	533	900	3,760,000	6,185,000	280	1960
X	Hydrocarbon	Hydrocarbon	620	30	3,340,000	5,300,000	425	1960
Y		N_2	1290	515	2,400,000	6,430,000	430	1960

(a) A responsible laboratory or contractor of U.S. Atomic Energy Commission.
(b) Psi. gage.
(c) Exclusive of cost of fissionable material.
(d) Total cost of programs.
(e) Fast breeder.
(f) Includes 110,000 kw. from fuel-fired superheater.
(g) Plus 8100 kg. thorium in blanket.
(h) Exclusive of research and development.
(i) About half from fuel-fired superheater.
(j) Plus 17,000 lb. thorium in blanket.

BORAX: Boiling water experiment.
EBR: Experimental breeder reactor.
EBWR: Experimental boiling water reactor.
HRE: Homogeneous reactor experiment.
LAMPRE: Los Alamos molten plutonium reactor experiment.
LAPRE: Los Alamos power reactor experiment.
NAA: Atomics International (North American Aviation Co.).
OMPRE: Organic moderated reactor experiment.
ORNL: Oak Ridge National Laboratory.
PWR: Pressurized water reactor.
SRE: Sodium reactor experiment.

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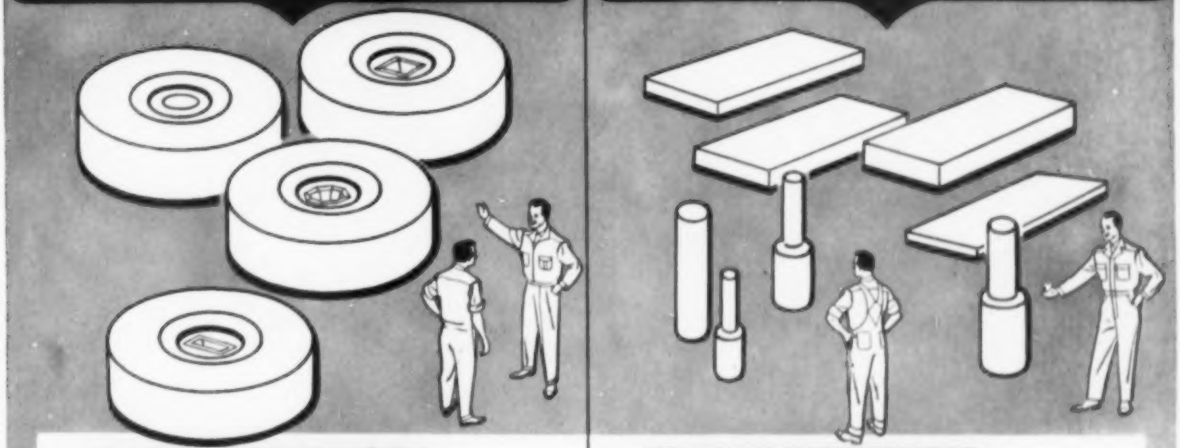

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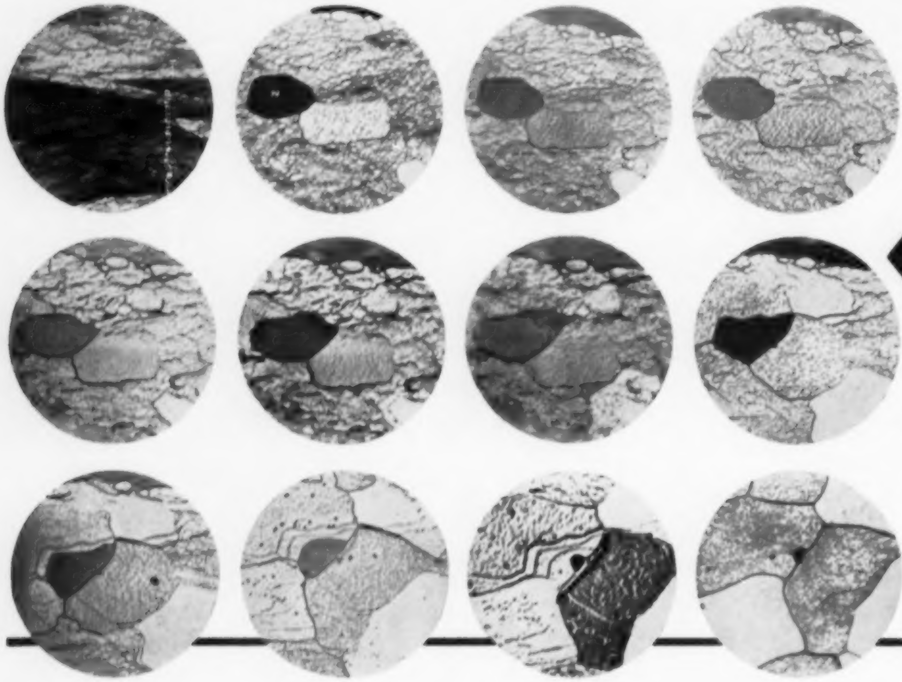

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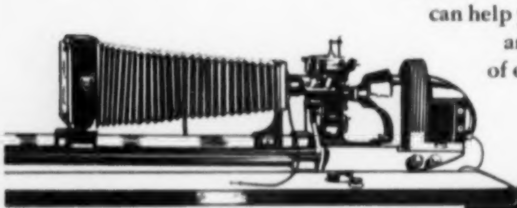

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Fig. 1 – 60-In. Coarse Crusher at E. W. Davis Works, Babbitt, Minn.

Magnetite Concentrates to Supplement High-Grade Iron Ore

*By E. C. WRIGHT**

As the high-grade Mesabi mines are being mined out, concentration of low-grade ore is coming ahead. One plant will make 3,500,000 tons of 63% iron pellets in 1956; another twice as large is under construction. (B 13, B 14, B 16, Fe)

A PREDICTION of future consumption of iron and steel, based on past performance of American industry, economics and population, indicates that our present consumption of 120,-000,000 gross tons of iron ore will rise to at least 150,000,000 tons annually by 1980.

Where are we going to get this much iron ore?

Let us examine the present sources. In round numbers the score in gross tons per year is:

From Lake Superior region	80,000,000
Other American regions	20,000,000
Imports	20,000,000

Imported tonnage is going up sharply – it doubled in the past two years – representing ore from Venezuela added to that from the older important exporters: Sweden, Cuba, Africa, South America. The figures will jump further when the Canadian deposits in Labrador start shipping. However, firm reliance could not be placed on any of these in an emergency (except perhaps the Labrador deposits), as we learned to our sorrow in attempting to bring the needed 3,000,000 tons of bauxite across the Caribbean during each of the World War II years.

Stockpiling of imported iron ore to the tune of, say, 100 million tons does not appear to be possible, politically. That means that in any future war the iron and steel industry will have to fall back on local sources of ore and scrap.

*Head, Department of Metallurgical Engineering, University of Alabama, and Consulting Editor, *Metal Progress*. Especial thanks are due to Fred DeVaney of Erie Mining Co., and Oscar Lee of Reserve Mining Co. for courtesies extended during visits to the Iron Range.

General View of American Resources

What is the situation in the iron ranges, which have been shipping close to 80 million gross tons of ore down the lakes in each of the last 15 years? Iron ore was discovered in Minnesota a century ago; mining was slow in starting and the amounts shipped prior to World War I seemed puny in comparison with the astronomical amounts thought to be available. However, now – 1956 – there is less than a billion tons of direct-shipping, high-grade ores remaining up there – certainly less than 20 years' supply even at the present rate. The U.S. Bureau of Mines estimated in 1950 that the "measured, indicated, and inferred" amount of direct-shipping ore and ore amenable to simple washing processes totaled 3,600,000,000 in Minnesota, Michigan and Wisconsin – 40 years' supply at present rate of 80 million annually, a rate which can hardly be exceeded in the declining life of these ore bodies.

Nor can we depend upon known ore deposits in other parts of the United States. There is a good deal of it scattered about, but iron ore is like many bulk commodities – you can't haul it economically very far. Population (uses and users) must move toward a land-locked deposit of hematite before it becomes ore. Nevertheless, we can take a look at the 1950 estimates of "measured, indicated and inferred" ore (direct-shipping or easily concentrated):

Northeastern states	380,000,000	gross tons
Southeastern region	1,627,000,000	
Missouri and Texas	64,000,000	
Western region	484,000,000	
Total	2,555,000,000	gross tons

This indicates a comfortable century ahead for that portion of our present scattered industry at its annual consumption of 20 million plus. It is the much larger fraction in the Midwest that depends on ore from the Lake Superior region which must do the worrying.

Fortunately for them there is a tremendous quantity of low-grade or marginal ores in that very region. The latest estimates by the U.S. Geological Survey and the Bureau of Mines (1950) show about 70 billion tons of rock containing 20 to 27% iron from which about 24 billion tons of concentrates containing 63% iron can be made. Of the latter, at least 20 billion tons can be made from the taconite rock of the Mesabi Range in Minnesota with about 1 billion from the hematitic jasper deposits of Wisconsin and Michigan. This could serve our expanding industry for over a century and is of course worthy of the attention given it during the past five years.

Producers of nonferrous metals long ago reached the end of high-grade ores in America. For over 40 years they have recoverd copper, zinc and lead from very lean and complex ores. Information as to operating processes and equipment for handling huge tonnages of low-grade ores was therefore available to the steel industry. Most of the practices and engineering equipment necessary for fine grinding of iron ore, and classifying, filtering, and agglomerating the fine concentrates, were developed long ago by nonferrous metal producers and many were readily adaptable to the beneficiation of marginal-grade iron ores.

The first engineer who realized the great potential of the taconite deposits was from the nonferrous metal industry – W. C. Swart, prominent in the development of large deposits analyzing about 1% copper. This was nearly 40 years ago. Working with E. W. Davis, director of the Mines Experiment Station at the University of Minnesota, he attempted to concentrate the magnetic taconites at Babbitt, Minn. Although this early work did not produce a marketable product at a competitive price, it explored many problems encountered in taconite mining and processing; Davis continued the studies at Minnesota and for 30 years has warned of the rapid depletion of the direct-shipping ores – for most of the time a voice in the wilderness.

The critical iron ore situation outlined in preceding paragraphs finally was realized after World War II. Development of foreign deposits and taconite pilot plants was suddenly intensified. What follows will be a necessarily brief account of the present status of the latter efforts.

Concentration of Magnetite

The term taconite refers to siliceous iron-bearing formations more than 100 miles long in the Mesabi Range in northern Minnesota. The western end contains iron oxide, mostly as hematite, totaling about 50 billion tons of low-grade ore; 5 to 6 billion tons at the eastern end contains most of the iron as magnetite. The chemical and physical structure of these rocks varies widely, and iron occurs as hematite, magnetite, siderite, limonite, and as silicates. Beneficiation processes must therefore be adapted to the type of deposit being worked.

Intensive laboratory research performed over the past ten years has shown that several different processes will have to be developed and carried

through the pilot plant stage before an appropriate plant can be built.

As far as is known at present, the most easily worked taconites contain magnetic oxide. The two largest full-scale plants now work these exclusively, by fine grinding through 100 mesh with magnetic separation of the mineral magnetite. Two other methods offer promise of eventual success at other places: *(a)* froth flotation of specular hematite in the ferruginous sandstones of the Marquette district of Michigan, and *(b)* reduction roasting of Mesabi hematitic taconite or Michigan jasper to produce an artificial magnetite for magnetic separation. Since the last-mentioned ores represent the largest reserves, they will be most important, potentially. Furthermore, they will require the greatest amount of research effort. The flotation process, which is so successful for sulphide ores of copper, lead and zinc, is not too efficient or economical on oxidized iron ores except the specular hematites of Michigan. The large proportion of material to be floated (30% as against 1 to 3% of the sulphide ores) also consumes a very high amount of costly reagent.

Operating plants on the magnetic taconite include a large one at Silver Bay, Minn. (Reserve Mining Co.). It has been operating for several months at the rate of 3,750,000 tons of concentrates per year. Erie Mining Co. has operated a pilot plant for several years near Aurora, Minn., producing 200,000 tons annually; from experience so gained a commercial plant for 7,500,000 tons of concentrates per year is now being constructed. Oliver Iron Mining Co. has studied taconite for many years, at first in a large laboratory in Duluth, and is currently processing over 800,000 tons annually in a pilot plant at Pilotac near the village of Mountain Iron, Minn.

Some of the more important difficulties to be hurdled were:

1. Mining the dense, hard taconite rock.
2. Coarse crushing of boulders sometimes 4 ft. in diameter.
3. Fine grinding to under 100 mesh.
4. Magnetic separation.
5. Agglomeration of the very fine concentrate into a form suitable for shipping and satisfactory for blast furnace operations.
6. Full-scale tests of the blast furnace feed at different steel plants.

The hard-rock mining problem which stymied the early enterprise at Babbitt, 40 years ago, has been overcome by the "jet piercer" of Linde Air Products Co., which uses oxygen to burn a blast hole at the rate of 18 to 20 ft. per hr. The blasted chunks are then crushed in huge gyratory crushers handling up to 4000 tons per hr. Fine grinding is in two stages: first to about 8 mesh in rod mills with classifiers and magnetic separators in closed circuit, followed by ball mills, classifiers and magnetic separators down to 80% through 320 mesh. The combined concentrates have little tendency to slime and are filtered to a cake which contains 8 to 10% water. The mined ore at Aurora contains from 18 to 25% iron as magnetite. The yield of concentrate averages 33% of the feed which requires the mining of three tons of taconite for one ton of concentrate. The analysis of the concentrate ranges from 61.5 to 64% iron with 7 to 9% SiO_2, and figures to a recovery of about 94% of the magnetite in the ore. Very similar figures were reported at the Reserve Mining plant at Silver Bay.

Considerable difference in practice beyond this point is evident at the various taconite plants and laboratories.

Fig. 2 – Looking East in Concentrator Building of E. W. Davis Works at Silver Bay, Minn., Showing Hydro and Magnetic Separators

Pelletizing

Despite much study and work by equipment manufacturers, there is still a large amount of discussion and difference of opinion about pelletizing. The fine concentrates cannot be sintered on a traveling grate without high dust loss. The wet concentrate must be formed into small balls or pellets in a rotating drum by adding about 0.5% of Wyoming bentonite for binder. Erie Mining Co. adds about 16 lb. of fine anthracite which is milled in the feed and makes ⅞-in. pellets. In the Reserve Mining Co.'s mill the wet pellets, about 0.4 in. or more in diameter, are rerolled in another drum and coated with about 30 to 40 lb. of coal per ton. (This coal supplies part of the heat required for the heat hardening of the pellets.)

Another method of forming balls is practicable but is still in the development stage. It is illustrated in Fig. 3. The rotating saucer or "ball well" makes any desired ball size and avoids most of the recycling. The most favorable size of pellet is also a debatable subject.

Hardening of Pellets

Thousands of laboratory and pilot-plant tests have been made to find the best method and furnace for hardening the wet pellets so they can withstand weathering in stockpiles, shipping long distances, rough handling, low dust loss, and smelting without disintegration. From this work and Swedish practices, it is now generally agreed that the pellets should be fired to 2300 to 2400° F., in a vertical shaft furnace or on a traveling grate. The heat required per ton varies from 700,000 to 2,000,000 Btu., depending on the furnace and also on whether the Fe_3O_4 in the pellets is oxidized to Fe_2O_3. This matter is important in a district where all fuels are costly – on the order of 60 to 75¢ per million Btu.

Four types of furnaces have been studied and the estimated heat requirements are as follows:

Rotary kiln nodulizing	2,000,000 Btu.
Open-top downdraft sintering machine	1,000,000
Closed-top recuperative traveling grates	1,300,000
Shaft furnace	750,000

The large plant of Reserve Mining Co. at Silver Bay has six recuperative traveling grates, each producing more than 2000 tons of fired pellets per day. These units were designed after several years of cooperative work by Reserve Mining Co., Allis-Chalmers, and Arthur G. McKee Co. in a pilot plant at Carrollville, Wis. The machine has a traveling grate 6 ft. wide and 170 ft. long; the pellet bed is 9 to 12 in. deep. The drying, preheating, and firing sections are completely enclosed; there are 28 separate wind boxes under the grates and six stacks on each machine, which permits both downdrafting and updrafting, with recuperation of hot gases from the firing and cooling sections for drying and preheating the wet pellets. While pellets are heated to over 2300° F., the magnetite is not completely oxidized to Fe_2O_3. They are then cooled to below 500° F., in a downdraft air cooler, and water sprays then quench the pellets on conveyers to the stockpile or ore boats. This is a well-engineered clean installation and a beautiful example of automation in the many control instruments which regulate the feeding, grate speed, and temperatures in the various stages.

E. W. Davis had studied the vertical shaft furnaces in experimental units at the University of Minnesota for many years. Likewise, engineers at Erie Mining Co. investigated the shaft furnace in their research laboratory at Hibbing. Many difficulties were encountered; the pellets would begin to fuse at 2450° F., uneven distribution of air caused hot spots and channeling; pellets stuck together in clumps or clusters which could not be discharged, and a round shaft appeared unsatisfactory.

The outcome of this work resulted in a rectangular furnace, 6 × 14 ft. in cross section and about 50 ft. high. On both sides of the wide section are combustion chambers from which enough fuel oil is injected into the bottom of the shaft to raise the temperature to about 1850° F. The hot gases are withdrawn and re-enter the main shaft 6 to 8 ft. below the top, and dry the bed of wet pellets as they descend into the firing zone. Excess air blown into the bottom cools the hot charge and then supplies oxygen for the coal in the pellets and to oxidize the Fe_3O_4 to Fe_2O_3 (an exothermic reaction which, by the way, supplies over 40% of the total heat requirements). In contrast to the ⅜-in. Reserve Mining pellets, which are mostly magnetite, the Erie pellets are mostly hematite and 1 in. in diameter. The shaft furnace fires 1000 tons of pellets per day; two of them have produced more than 1,000,000 tons in the past seven years.

About 3.5 gal. of light fuel oil per ton is burned, and the over-all thermal efficiency is much higher than in the other types. By close control of the maximum firing temperature (2400° F.) and the amount of air blown,

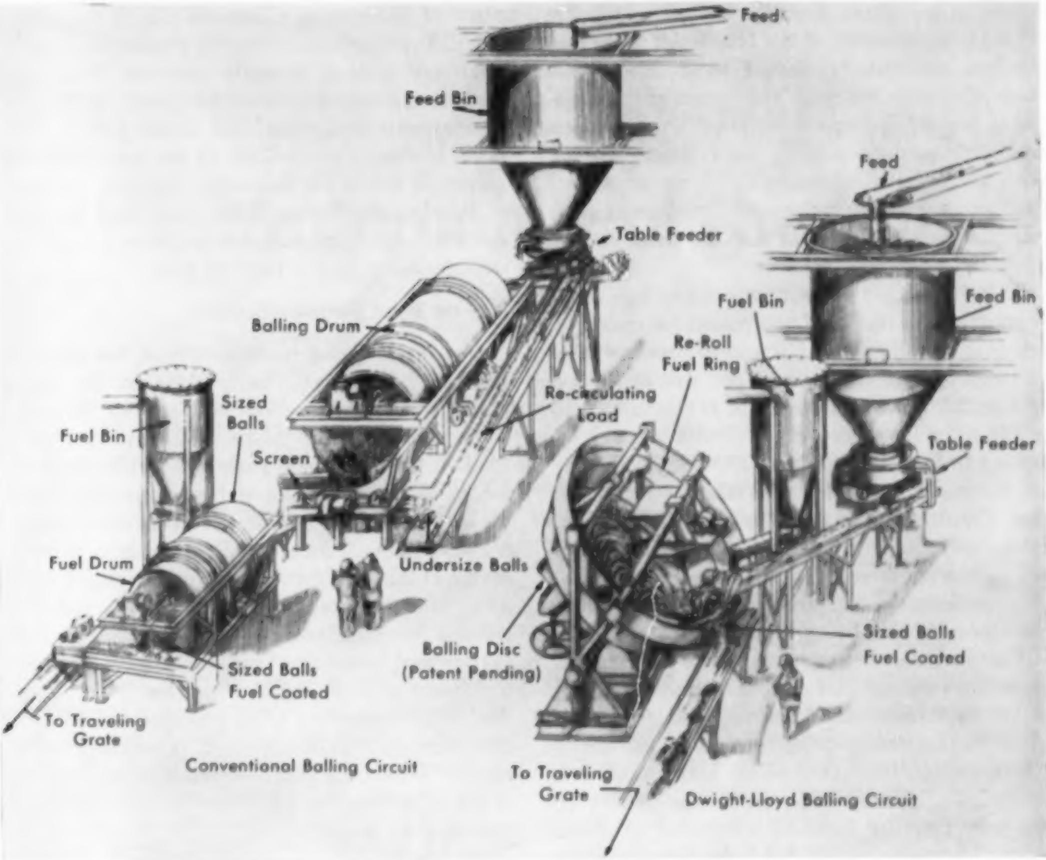


Fig. 3 — Conventional Balling in Drums as Compared With Dwight-Lloyd "Ballwell Balling Disk". Courtesy McDowell Co., Inc.

incipient fusion and cluster formation are controlled. A water-cooled shaft and cross arms in the bottom of the furnace break up any clusters.

This shaft furnace is a highly efficient and smoothly operating piece of metallurgical equipment. It is not too much to say that the furnacing problem had to be successfully solved before the firm could go ahead with the construction of the $300,000,000 concentration plant near Aurora.

Concentration of Hematite

Most of the present developments are based on the magnetic taconite. Plants now erected or under construction can operate for more than 50 years on the magnetic ores and reach an annual output of more than 15,000,000 tons of this high-grade concentrate. It can be seen, therefore, that this source can supply all or a major fraction of the domestic ore needed during the next few decades to supplement the dwindling supply of high-grade shipping ore from the Mesabi.

Most of the taconite deposits of the Mesabi Range contain hematite rather than magnetite. A further 3 billion tons of jasper, taconite, and ferruginous cherts are located in the Michigan-Wisconsin iron districts. Most of this contains 30 to 35% iron and cannot be concentrated by magnets in its natural state. Although large sums have already been spent studying these marginal ores, the results have been generally unfavorable technically and economically. Since the iron-bearing minerals are in very fine particles (under 100 mesh), extremely fine grinding is necessary to liberate them. Flotation is the only known process to handle such finely ground pulps. Much work with a wide variety of flotation reagents has yielded discouraging results (with one exception) so the whole problem of how to process the enormous reserves of hematitic low-grade ores still remains unsolved.

The one exception is a full-scale plant of the Cleveland-Cliffs Co., near Ishpeming, Mich.,

where a deposit of specular hematite is being mined in an open pit at the Humboldt Mine and the ore successfully floated to a concentrate containing over 60% iron. Since most of the high-grade direct-shipping ore produced in this region comes from deep underground mines, mining costs are high and operators in this region believe that concentrating costs on low-grade ores from an open pit might be less than the extra mining costs underground.

This Humboldt concentrator started in 1954. It contains conventional equipment for crushing, grinding, flotation, and filtering to produce 2000 or more tons of concentrate per day at a ratio of 1 to 2.33. Concentrates with 60% iron and 10 to 12% silica have been shipped without agglomerating to Ford Motor Co. in Detroit where they are sintered after mixing with other ores and flue dust. Construction of a similar plant at Republic, Mich., containing two additional flotation lines will give a combined daily output of about 7000 tons. Pelletizing and traveling grate sintering machinery is also being erected.

The specular hematite in these ores has a plate-like structure, an odd characteristic which makes the form amenable to simple flotation with a low reagent consumption. Only 1 lb. per ton of a mixture of fatty acids (oleic and linoleic) is consumed; for successful results the density of the pulp must be carefully controlled at about 40% solids, and the pH held closely within 6.9 to 7.1 limits.

Pelletizing and firing of the hematitic concentrate presented special problems which had to be overcome. Working closely with McDowell Co., the pelletizer nicknamed the flying saucer has been developed. This saucer is somewhat like the one shown at the right of Fig. 3, except it has shelved surfaces so that balls of various diameter may be obtained without recycling the fines; centrifugal force throws the large balls to the outer periphery and over the lip on the conveyer feeding the sintering machine.

At this time the status of the low-grade hematitic ores other than the specular variety is very uncertain. Experimental roasting in a reducing atmosphere to produce magnetic particles is being done at Jones & Laughlin's research laboratory at Negaunee, Mich., and in a pilot plant operated by Republic Steel Corp. and National Lead Co. in the Birmingham, Ala., district. Erie Mining Co. has developed a shaft type of roasting furnace for treating such ores, and another furnace of this general design has been in successful operation for the past three years at the plant of Manganese Chemical Co. at Riverton, Minn. The synthetic magnetite coming from such treatment is more strongly magnetic than natural, can be separated from the gangue of the ore by magnetic separators, and is much more difficult to demagnetize. Due to the enormous reserves of low-grade hematite ores, the solution of this beneficiation problem may well become the most important research problem facing the steel industry in the next 20 years.

Use on Blast Furnace Burden

One of the great uncertainties of the present situation relates to the performance of the high-grade concentrate pellets in the blast furnace. Although much more than a million tons has been smelted into pig iron at various steel plants, some inconclusive results have been reported. The present author can find no one in the steel industry who will venture a definite opinion as to coke saving at the blast furnace, increased output with a 62% iron ore instead of the present 50%, and decreased smelting costs from lower flux in the burden and lower overhead. Since most of these tests were of short duration and the pellets handled were themselves of an experimental nature, this situation is to be expected. It will take some months – maybe a year – of full-scale operations at the blast furnaces before any accurate evaluation may be made.

The whole economic status of taconite concentrates is thus shrouded in some mystery. Costs are greater than direct-shipping ores because three tons of rock must be mined instead of one, a huge capital charge will apply for the amortization of the processing plants, plus the extra operating expense of concentrating and agglomerating. On the credit side, the high-grade pellets will be free from *ad valorum* taxes levied by the state governments on unmined ore, a much lower royalty fee (at least for the present), reduced shipping charges per ton of iron handled, and a credit for the expected blast furnace economy in smelting a tailor-made, uniform high-grade concentrate.

In spite of these uncertainties, the steel industry simply must solve the problem of using the low-grade hematitic ores of the iron ranges. Beneficiation of magnetic iron ores on a large scale has finally been proven to be possible. It should grow into one of the largest industries in the country. More than $600,000,000 has already been spent for research and new plants, and many times this amount will have to be added in the next few years to attain the required annual output of 35,000,000 tons of concentrates.

Materials in the Automobile of the Future

*By A. L. BOEGEHOLD**

The future family car will be no smaller than present models; it will weigh less because of generous use of light metals. The spark ignition gasoline engine will persist, but will be more efficient and lighter, even if more powerful. (T 21)

THIS SUBJECT should certainly be of great interest to a metallurgist – and to everybody else for that matter – for, as C. F. Kettering says, "We should all be intensely interested in the future because that's where we are going to live for the rest of our lives!"

Before we talk about future materials, we must have some idea of what the future automobile will be, and any prediction must depend on reasonable assumptions. One assumption is that the causes that have operated to produce present day effects will continue to operate along similar lines, and produce effects in the future from present-day causes. Let us list some of these causes that have been operating in the past.

1. Engineers by nature are impelled to get greater efficiency in the job of transporting personnel and cargo.

2. Conservation of both fuel and metal resources is a strong urge, and is responsible for part of the desire for *(a)* greater efficiency, *(b)* elimination of strategic materials, *(c)* utilization of materials in greater supply, and *(d)* use of fuel in a manner consistent with conservation.

3. These objectives must be attained at a cost that will create an increasing sales volume and standard of living.

Now let us consider each of these items in some detail.

Efficiency includes first, the mechanical and thermal efficiency of the power plant; second, the mechanical efficiency of each mechanism in the vehicle and third, the over-all efficiency in terms of resources consumed. This boils down to:

First, a power plant that is most efficient to operate and build and that needs the smallest quantity of strategic and scarce materials.

Second, a vehicle of lowest over-all weight compatible with cost and use of plentiful materials. Low weight must not sacrifice present-day interior roominess. In other words, we are not heading toward a small car.

The above two paragraphs indicate how all three of the causes listed are intertwined – efficiency, conservation and sales volume. So it will not be surprising if I next turn to the last mentioned.

Production – Consider the statistics assembled in Table I on population, car usage, and fuel consumption. Even though the fuel bill for 1955 has been cut by progressive economies through increased compression ratios and higher octane gasolines, the total fuel consumed in 1980 will be almost double due to increased number of cars and increased mileage per car. An 83% increase in gasoline production in the next 15

*Manager of Research Staff Activities, General Motors Corp., Detroit; Past President of ⊕. This paper is a shortened version of a talk before the Cleveland District, A.S.T.M., April 12, 1956. He wishes to acknowledge the help of many of his associates at G.M. Research Center, Detroit.

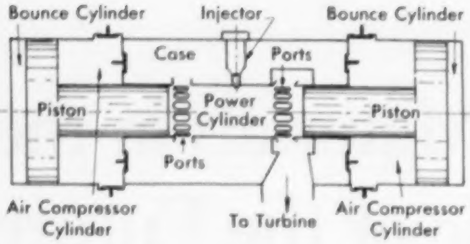


Fig. 1 – Idealized Cross Section of Free-Piston Engine in Starting Position. All valves closed

Fig. 2 – Operating Sequence

years will be *very* difficult to guarantee. To avoid trouble, another way to reduce fuel consumption, besides more efficient engines, must be found. If each car weighed only half as much, the fuel needed to move it along the road would be considerably decreased. This means that lighter materials of construction must be used, and power plants which have the lowest weight per horsepower developed or selected. This results in using less metal, more of the plentiful metals, and less fuel.

The superhighway program can be counted on to force automobile construction in the direction of lower weight and better fuel economy. Highways will very likely be financed by a tax on gasoline. As gasoline cost increases, the automobile owner will turn to less thirsty cars. This situation in Europe has produced the pint-sized car, which, with generous use of aluminum and magnesium, may weigh about 1600 lb. Although it is unlikely that we will sacrifice roominess and comfort to anything like this extent, we will see better fuel economy per ton-mile of car operation resulting from lighter cars.

Table I – Population, Automobile, and Fuel Statistics, 1930 to 1980

	1930	1940	1955	1980
Number of automobiles	23,000,000	27,000,000	52,000,000	88,000,000
Population of the U.S.	123,000,000	132,000,000	166,000,000	220,000,000
Persons in U.S. per auto	5.3	4.8	3.2	2.5
Average annual mileage	7,200	9,200	9,600	12,000
Miles per year per person	1,300	1,900	3,000	4,800
Average horsepower	75	125	180	250
Miles per gallon	15	18	20	30
Gallons of fuel; millions	14,000	21,000	46,000	84,000

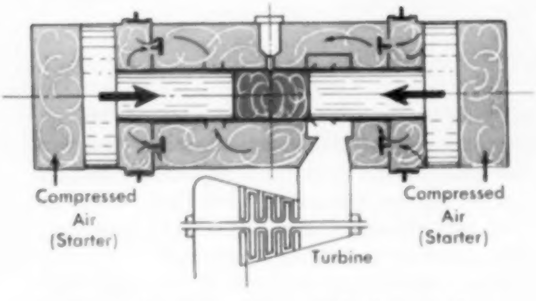
Power Plants

How do various power plants now available compare in this respect? Table II, p. 106, gives some information, and it would seem that the gas turbine (considered by many to be the coming power plant) compares well with the present-day piston engine in weight, can be put in less space, and can use low-grade fuel, but we need much information on how to get along with less scarce alloy such as nickel in the turbine blades.

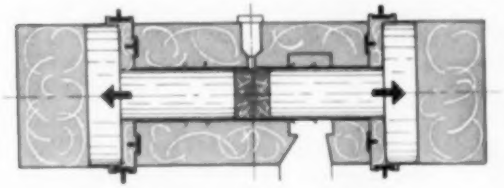
One way to eliminate much of the need for nickel or cobalt in the turbine blades would be to keep them at a low enough temperature. This has been done both abroad and in this country by liquid cooling; this, however, requires a condenser and radiator to cool the liquid used for blade cooling, and this added complication would sacrifice the weight advantage in favor of the gas turbine. (Another way is to feed cooler gas to the turbine, and that will be described later under the topic of "free-piston engine".) A point that has yet to be cleared up is whether the gas coupling between the gasifier and the power turbine will provide the acceleration now demanded in passenger cars. Even though its fuel appetite is on the high side and the exhaust gases must be adequately disposed of, the gas turbine will certainly find uses in certain areas such as sport cars and possibly cargo carriers.

Diesels will continue in busses and trucks, boats, and a variety of steady power units, because of the low consumption of cheap fuel. Their weight is necessary to achieve durability while operating a great percentage of time at nearly full power output. A turbo-blower increases both power output and fuel efficiency.

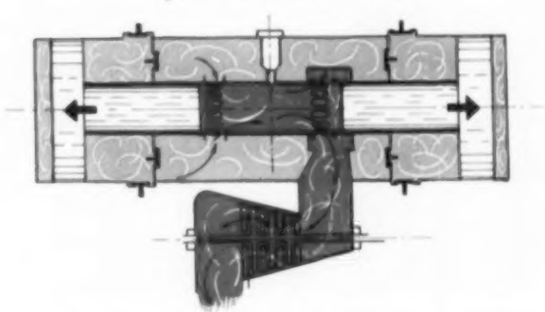
Furthermore, numerous aluminum parts will substantially reduce weight per horsepower and decrease unit size. An aluminum diesel would weigh about 7 lb. per hp. Even this would not be suitable for passenger cars. We can design a diesel engine of lighter construction, but do not anticipate a development in this direction.



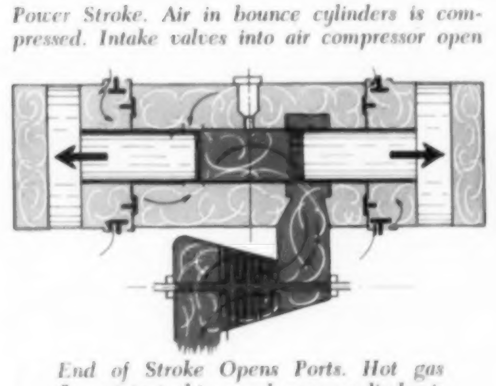
Compressed Air to Bounce Cylinders, to Start. Pistons move inward, closing ports, compressing air in power cylinder, and pumping air into case



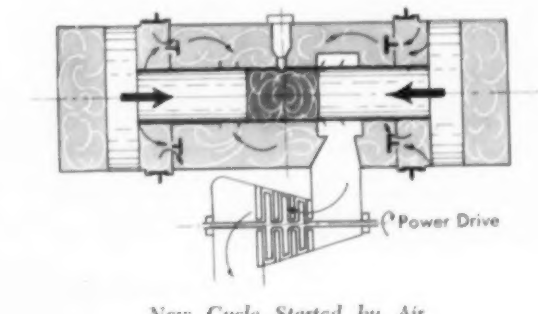
Fuel Injected Into Power Cylinder at End of Stroke



Power Stroke. Air in bounce cylinders is compressed. Intake valves into air compressor open



End of Stroke Opens Ports. Hot gas flows into turbine, and power cylinder is scavanged by compressed air from case



New Cycle Started by Air Pressure in Bounce Cylinder

Free-Piston Engine

The free-piston engine may be a strong competitor to the spark ignition piston engine for passenger vehicles 25 years hence because it can operate on almost any kind of liquid fuel, it is economical to build, and its fuel economy is nearly as good as the diesel's. It is not a new device; over 1200 air compressor units are now in operation; these are quite heavy and are usually rated at about 1000 hp. However, the fact that an engine may be able to burn a lower grade fuel will probably not be an over-riding factor. We have seen how the cost advantage at one time enjoyed by kerosene over gasoline has all but disappeared.

Figure 1* shows the engine and Fig. 2* the operating sequence needed to convert gas horsepower from it into shaft horsepower by way of a gas turbine. There are two pistons opposing each other in a single cylinder. Each piston is constructed with a smaller diameter for the power end and a large diameter for the air compressor end. In Fig. 1 the pistons are shown at the extreme outward point of travel. The space behind the large-diameter pistons contains air that is compressed by the outward motion of the pistons and bounces them back together again. When the pistons have reached the extreme inward position, an injector forces fuel into the highly compressed air, which burns explosively and blows the pistons apart again. The cycle is diagrammed in five steps in Fig. 2*.

During the inward stroke, the large pistons compress the air in the spaces labeled "Air Compressor Cylinders" and this is forced into the casing surrounding the power cylinder. When the outward motion of the two pistons uncovers the ports, the compressed air in the casing rushes through the intake ports at the left and scavenges the burned gasses from the power cylinder, pushing these through the exhaust ports and passageway at the right end into the turbine.

This turbine operates at relatively low temperatures. Whereas the conventional gas turbine uses gas at 1600 to 1700° F., the turbine driven by gas from the free-piston engine operates at 850 to 900° F. The material for turbine blades therefore does not pose a problem of scarce refractory alloys. The advantage of simplicity of the free piston engine, however, may be lost by the complexity and expense of the turbine

*From "The GMR 4-4 Hyprex Engine", by A. F. Underwood, General Motors Research Staff, presented at Society of Automotive Engineers' summer meeting, June 3, 1956.

needed to produce shaft horsepower. For good efficiency, it must have four or five banks of rotating blades, each with a bank of stationary deflecting blades. This adds greatly to the over-all cost of building the whole free piston-turbine power package. A radial inflow turbine may be the solution here.

The principal advantage remaining in favor of this engine is that it burns low-grade fuels, such as kerosene or mixtures of Bunker C and kerosene. (Bunker C alone must be treated.) It would appear, therefore, that if free-piston engines ever become the universally used power plant for passenger cars, the output of the petroleum industry would undergo a radical change. In the field of cargo-carrying vehicles, where durability and fuel consumption are important, the free-piston engine will meet competition from the turbo-blown diesel, the regenerative gas turbine, and the high-compression gasoline piston engine made more rugged to stand steady, high-output operation.

Piston Engine (High Compression)

How will the gasoline piston engine fare? In the foreseeable future, the petroleum industry will have gasoline of high enough octane rating at the fuel pumps to permit compression ratios as high as 12 to 1 or 13 to 1. This can be anticipated from the rate of increase since 1947, when C. F. Kettering demonstrated that a car with 12 to 1 compression ratio saved at least 30% of the fuel used in the then current cars with compression ratios of 6 or 7 to 1.

While compression ratios of 13 to 1 will require gasoline of higher octane rating, past performance of the petroleum industry indicates that we can expect to have the desired fuel at that time. Passenger cars will then be operating with a fuel economy comparable to that of diesel engines and free-piston engines. The fuel, however, will be quite different; it is not now available at filling stations, but will have an octane rating of 110 to 120 on the present scale.

As a result of improved fuel economy, lower unit weight and lower unit size, graphically shown in Fig. 3, the gasoline piston engine will be in a strong position to retain its place as the power plant for the future automobile. If we consider that the most desirable engines are those having the shortest bar height in the three categories shown, then it is obvious that gasoline engines are in the most favorable position, especially the engines built with a large proportion of aluminum. These show better fuel economy and lower weight and space requirements than any others. Added to that, all of our manufacturing plants are tooled for production of this type of engine; introduction of a radically different one would involve stupendous costs. There is no doubt, however, that the money would be spent just as soon as another engine shows a clear advantage.

Trend – The trend for the next 15 years, then, would appear to be toward higher compression ratios and the use of more aluminum and magnesium. We can also expect ventures involving gas turbines or free-piston engines, probably at

Table II – Comparison of Engine Types

Engine	Fuel Consumption*		Weight†	Size‡	Fuel
	At Max. Power	At Best Economy			
Spark ignition piston engines					
Cast iron, 9 to 1 compression ratio	0.48	0.41	3.6	9.1	95 octane
Aluminum, 12 to 1 compression ratio	0.44	0.38	2.2	8.4	110 octane
Aluminum, 8 to 1 compression ratio, turbo-charged, 30% boost	0.49	0.43	2.1	2.1	95 octane
Gas turbines					
Regenerative	0.75	0.75	3.6	3.6	Kerosene
Regenerative (projected)	0.60	0.60	3.0	7.2	Kerosene
Diesel engines					
4-stroke cycle	0.41-0.47	0.38	12.7	26.0	No. 2 diesel
2-stroke cycle	0.42	0.40	12.1	14.8	Kerosene
2-stroke cycle, exhaust-turbo blower	0.42	0.41	11.7	13.6	Kerosene
Free-piston engine	0.48	0.48	3.6	7.0	Kerosene, gasoline or diesel

*Pounds per brake horsepower per hour †Pounds per brake horsepower
‡Cubic feet per 100 brake horsepower

first in sports cars. We can also consider the possibility of turbo-supercharging in commercial engines and sports cars to get better fuel economy and increased horsepower per unit of size. Passenger cars run at reduced load too much of the time to make turbo-chargers profitable.

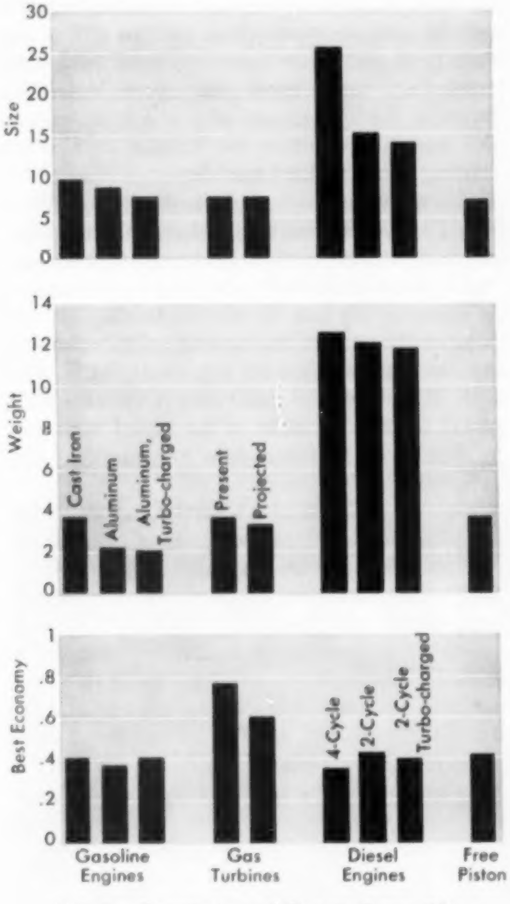


Fig. 3 – Comparison of Engine Types. Vertical ordinates are defined under Table II

Light Metals

In Critical Points for March 1956 the Editor of *Metal Progress* discusses the topic "Light Metals in Our Two-Ton Autos?" This is a matter mentioned in the third paragraph of the present article, namely, conservation of metal resources. Even though we are accustomed to a prodigal use of iron in all our modern tools, machinery, and equipment, a look at the availability of metals on the earth or in the ocean suggests that the colossal annual consumption of metal for automobiles could be better switched to one that is in greater supply – namely, aluminum or magnesium. The use of iron is especially prodigal in view of the attrition by corrosion which scatters this metal beyond recovery. The automobile industry buys 25% of the total steel production. If a substantial part of this were replaced with light alloys and plastics in some form, the increasing rate of depletion of our iron ores would be given a much-needed brake. The trend toward more light metals has been going on ever since World War II. Before that about the only aluminum in our automobiles was in the pistons, and in some makes these were cast iron. All have now gone to aluminum pistons.

Some form of die-cast aluminum cylinder block will be the basis for reducing engine weight. (This is a logical extension of the change to aluminum that has already taken place in automatic transmissions.) The intake manifold will be aluminum and the exhaust manifold will remain cast iron. The pistons will continue to be aluminum alloy. The low expansion possessed by the present piston alloy may be modified to something compatible with wet aluminum liners, which, of course, will be faced with some wear resistant material comparable to chromium plate, or better.

Automatic transmissions are accountable for another sizable increase in aluminum usage. When the total costs of the finished components are compared, aluminum competes with cast iron or malleable iron. Although the cost per pound of aluminum is high, the cost per piece is sliced to one-third because of its light weight per cubic inch. Cost per cubic inch of iron and aluminum is nearly the same. Machining cost for aluminum is much less, and many parts (which can be made as die castings or permanent mold castings) are closer to finish dimension than iron castings and therefore require less machining.

Another change in the automobile which will lower the weight and save scarce materials will be in the radiator. As copper becomes more expensive and scarcer, the urge to replace it with aluminum will become greater. By 1980, I expect our radiators will be made of aluminum.

The average 1930 car used 4 lb. of aluminum; by 1945 this had only doubled, but by 1955 it had jumped up to 35 lb. Some cars were using 70 to 80 lb. and Cadillac's "Eldorado" contained 192 lb., replacing some 400 lb. of steel. Hence a prediction of 80 lb. per car by 1965 does not seem unrealistic. Another forecast by a leading

engineer in the automobile industry is 100 lb. of aluminum in each of the 8,000,000 cars expected to be built in 1970. This would be equal to the total aluminum production in 1949!

Magnesium's cost per cubic inch is higher than aluminum's, so the present competition from cast iron has prevented much substitution. However, we may expect that oil pans and gear box covers will be die-cast magnesium. In considering eventualities, it is well to keep in mind that each cubic foot of ocean water contains 1 oz. of recoverable magnesium. This doesn't sound like much, but the magnesium in 1 cu. mi. of ocean water would provide 175 lb. of magnesium for every one of the 52,000,000 autos now in the U.S.! Certainly the supply of this metal is truly inexhaustible.

If I do not make some reference to the possible use of titanium in the future automobile, someone is sure to ask about it. No mention has been made because we do not see a legitimate use for it even if the price were low enough to compete. The structure of the automobile is such that weight can be more easily saved with aluminum and magnesium than with titanium. One possible exception would be for gas turbine components operating between 500 and 1000° F., where aluminum or magnesium alloys would be inadequate.

Parts for Engines and Drives

In this brief review, mere mention can be made of many items, each warranting considerable discussion. Valves, for example. Valves will continue to be of heat resisting alloys, universally aluminized, both intake and exhaust. "Aldip" coating more than doubles the life of the valves.*

Piston pins and connecting rods will probably see no change.

Bearings will continue to be steel-backed inserts made by powder metallurgy similar to "Durex 100" or "Moraine 400". The first consists of a copper-nickel porous sintered matrix bonded to a steel back and overlaid and permeated with a lead-base babbitt. The second consists of an aluminum-base silicon-cadmium alloy bonded to a steel back and a thin overlay of lead-base babbitt.

The crankshaft will be made by the process that will result in the lowest cost without sacrificing any engineering requirement. The two principal contenders seem to be automatic forging of steel and shell-molded cast pearlitic malleable iron, or shell-molded ductile iron. The large investment in automatic forging equipment now existing in some plants constitutes a major obstacle in the path of change to cast crankshafts. My forecast, however, is that the savings yet to be made in shell molding will make the cost so much in favor of the cast crankshaft that it will be ultimately accepted. (About 25% of the cars produced have been equipped with cast crankshafts for a good many years.) Another factor is the appearance of new alloys, such as the one in production for Pontiac crankshafts starting with the 1955 models.

Shortages in alloying elements during World War II gave impetus to a change in the composition of the steels used in gears, shafts, and other highly stressed members. Our new understanding of hardenability and its relation to alloy content pointed the way to the correct substitutions for the steels relatively high in nickel. S.A.E. 4615 with 1¾% nickel and 8620 and 8640 with 0.65% nickel account for most of the nickel now used in alloy steels in automobile construction today (excluding valve steels).

Nickel is still in short supply, and is quite likely to remain so. Consequently I believe that the future car will use no nickel in the steels for shafts and gears. Great success has already been had with a steel containing 0.50% molybdenum and 0.50% manganese as a substitute for S.A.E. 4615. By adjusting the molybdenum in this composition downward to obtain hardenability in the range of S.A.E. 8620 and 8640, even these could also be dispensed with.

So much for the conventional power plant. What of the suggested *new* ones – the gas turbine and the free-piston engine.

Gas turbines so far built have used much alloy to avoid any possibility of failure. One 200-hp. gas turbine weighing 700 lb. had 76 lb. of nickel in it. It is obvious that any extended use of such a power plant must involve lower alloy materials. It is reasonable to assume from a study of each part that the same turbine could be made with materials that would perform satisfactorily with a total of 7.5 lb. of nickel and ultimately with as little as 4.75 lb. per engine. Heat resistance in sufficient degree will be achieved in most parts with chromium steels or by aluminizing plain carbon steels. The next 25 years will also see the invention of new alloys for those turbine parts which need to operate at 1300 to 1700° F.

*See "Engine Valves Improved by Aldip Coating", by R. F. Thomson, D. K. Hanink, E. B. Etchells, and K. B. Valentine; S. A. E. Meeting, March 1, 1955.

The free-piston engine can be built with metals containing no nickel. The structure of the air chamber and compressor housing could be aluminum alloy for weight reduction; the pistons could be partly of cast iron, and partly of aluminum, to obtain the proper weight for speed control. The cylinder sleeves are steel, heat treated to high physical properties. The compressed air chambers and passages are formed of low-carbon steel. The turbine would have rotor and stator blades of Silcrome No. 1 containing only chromium and silicon, and the case would be pearlitic malleable iron.

Conclusion

Following the example frequently set by the stock market analyst and by some war correspondents, I have now predicted a sufficient range of possibilities for the future so that, when the time comes, I can say that the events were predicted 25 years before. All we have to do now is to get on the job to find out how close to the forecast the future will be.

All I have been saying thus far can be boiled down to a few sentences:

1. Engine and car weights are going down.
2. Engine efficiency will increase.
3. We will use light alloys generously to supplement increased efficiency as a means of conserving fuel.
4. Otherwise, materials will be much the same as now but with less nickel and with more pearlitic malleable iron.
5. The power plant used in the future will have low weight and low volume per horsepower, and will have good fuel economy.

The race between the present type of engine, the gas turbine, and the free-piston engine will be exciting. Size, weight and performance of the gasoline piston engine, which must be exceeded by the gas turbine or the free-piston engine if they are to displace it, are targets that will not stand still. However, improvements we can see in the immediate future indicate that piston engines will drive our automobiles for many years to come.

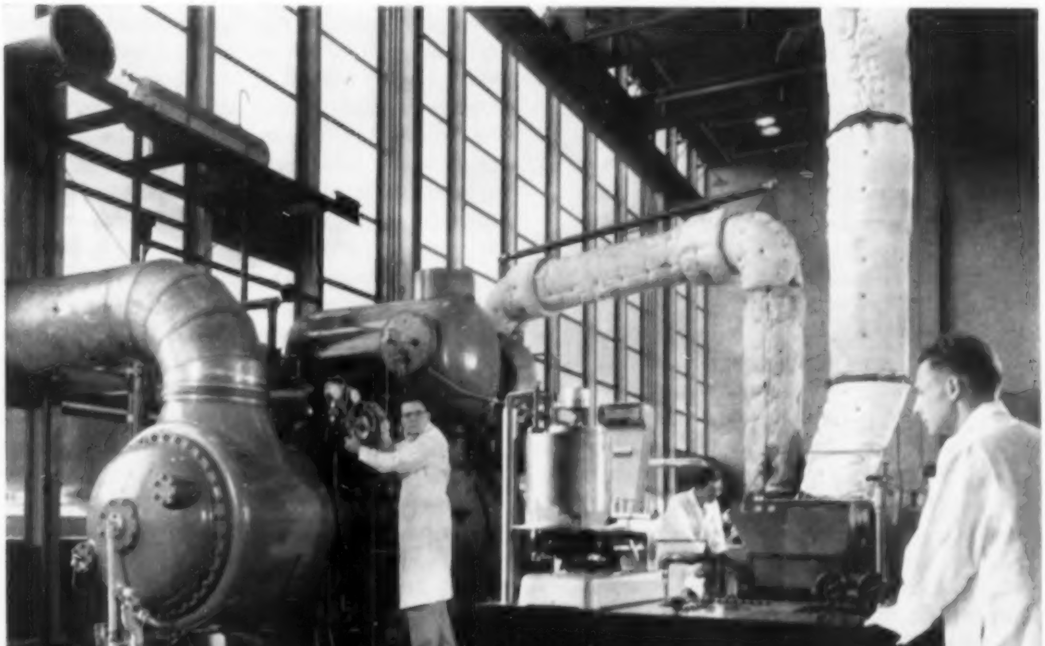


Fig. 4 – Many Free-Piston Engines Are in Use as Air Compressors, but Here We See a Free-Piston Gasifier Under Test – Similar to Six Units General Motors Is Building for the U.S. Maritime Administration for Transatlantic Service

Forming Sheet Metal Components for Aircraft

By JOHN F. TYRRELL*

Designs of aircraft change so rapidly that few sheet metal parts are ever produced in appreciable volume and some unique techniques have been developed to minimize retooling cost. (G general, SG-j)

Forming departments in the aircraft industry bear a family resemblance to those in the automotive and other mass-production industries, but their operation involves problems rarely encountered elsewhere. Only during wars are aircraft designs frozen so there can be continuous production of identical components. In peacetime, retooling rather than production is almost continuous, not only because of new planes but also because of modifications in design of "production" models.

The kind of tooling selected for fabrication of sheet metal parts is determined from the best estimate of the number of the parts to be produced, the dimensional tolerances and the kind of material. Seldom are more than a thousand or even a few hundred units produced; a regular "production" run may be ten to twenty components and occasionally only one or two are required. Prior to World War II, the one and two-unit orders were the rule rather than the exception and parts were often formed by hand with a hammer over a bag of sand or a wooden form block.

Hand forming requires the minimum investment for tools and often would be the cheapest method of forming a small number of parts if dimensional tolerances could be met. Unfortunately, aircraft designers now insist on a degree of accuracy in each component which was unheard of in prewar planes and which cannot be obtained consistently by even the most experienced craftsmen with hand tools. Recently, forming by peening has been revived but instead of a hammer, shot-blasting equipment is used. With proper control of the shot, pressure and nozzle motion, simple shallow contours can be formed quite accurately at low cost on fairly heavy structural parts.

Most sheet metal parts, however, must be formed on dies because of the shape and accuracy required. The conventional method is to make a punch and a die from a material which will wear long enough to produce the number of parts required. Amortization of such dies would be extremely expensive in aircraft production because of the comparatively few parts made, so a number of ingenious methods have been developed to eliminate the need for either the punch or die.

In the Guerin process, only a punch is used and a confined rubber pad is used as the female die. The sheet to be shaped is placed on the punch and a thick rubber pad forced down on the sheet. The sides of the pad are confined in a steel box and the punch is placed on a steel plate which enters the rubber box. The hydrostatic pressure developed in the confined rubber forces the sheet to conform to the shape of the punch.

The process was developed at Douglas Aircraft Co. early in World War II and was quickly adopted by other aircraft companies for form-

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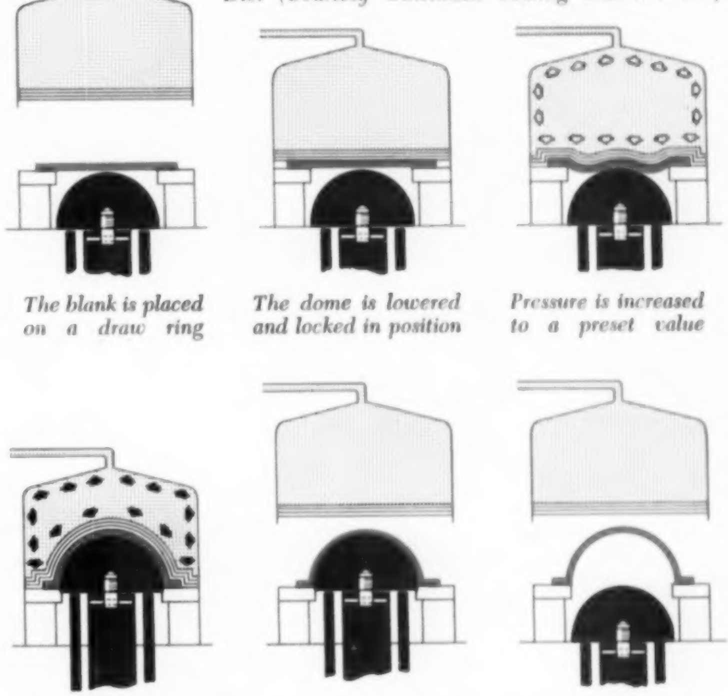
ing shallow flanged parts or for making the shallow depressions used to increase rigidity of flat panels. The depth of drawing is usually limited by the thickness of the rubber pad but can often be increased locally by placing small pieces of rubber over the blank on areas which require maximum deformation.

This limitation on the depth of draw is not the only disadvantage of the Guerin process; the initial contact of the rubber and blank can move the blank out of position, so it is necessary to use positioning pins in the punch with holes in the blank to correspond. Although such holes are often specified in aircraft components for weight reduction, they definitely reduce the number and variety of parts which can be formed by this method.

In the Hydroforming Process, Hydraulic Pressure Acting on a Flexible Diaphragm Serves as a Female Die. (Courtesy Cincinnati Milling Machine Co.)



The blank is placed on a draw ring — *The dome is lowered and locked in position* — *Pressure is increased to a preset value*

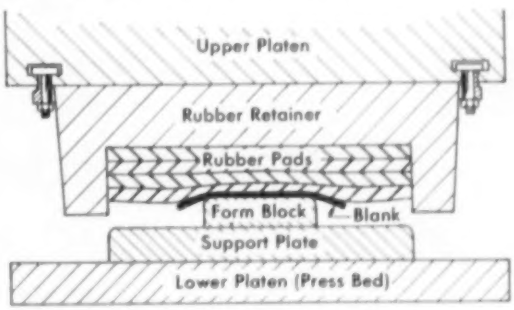
The punch is raised to form the part — *Pressure is released and the dome raised* — *The punch is withdrawn from the part*

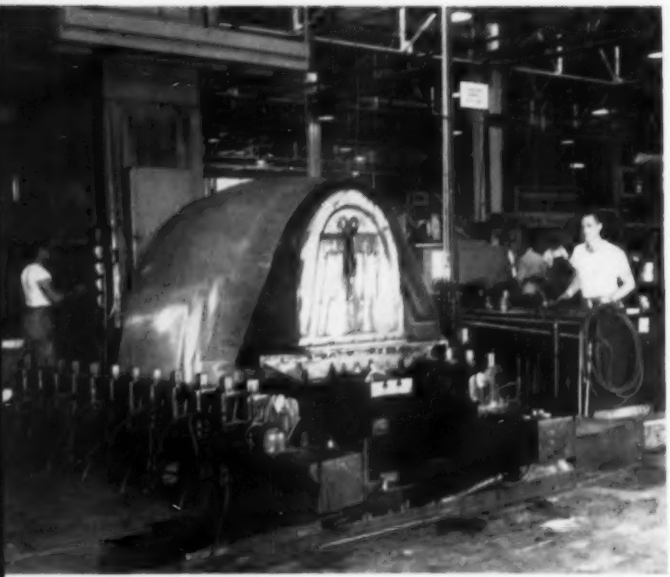
These limitations have been partially overcome by the newer Verson-Wheelon press in which the rubber pad is replaced by a hydraulic cell covered by a thin rubber diaphragm. The steel plate carrying the punch and blank remains fixed. As the hydraulic pressure is increased, the flexible diaphragm covers the blank and forces it down and around the punch. The forming pressure is much greater than that obtainable in the Guerin process and is uniform on all sides of the punch and in all directions. Deeper draws and better side detail are possible and yet the equipment is much simpler and cheaper than conventional hydraulic or mechanical presses of the same capacity.

When either process is used to form small parts on a large press, a number of punches can be used simultaneously to cover the full area of the steel plate. To reduce idle time of the press, four or six movable plates are used so that while one group of parts is being formed, others are being loaded or unloaded.

Hydroforming is another method of forming drawn parts which uses hydraulic pressure acting on a flexible diaphragm as the female die. The punch is in the center of the press with a draw ring mounted on the support slightly above the top of the punch. The blank is placed on the ring and the hydraulic dome is lowered over it and locked in position. The pressure is increased to a predetermined value and then the punch is raised to force the blank into the high-pressure fluid. Forming pressures as high as 15,000 psi. can be developed and are uniform over the entire

Rubber Pads Are Used Instead of a Female Die in Forming Shallow Aircraft Parts by the Guerin Process





Stretch Forming an Aircraft Component by Forcing a Form Block Into a Sheet Whose Edges Are Held in Fixed, Parallel Jaws. (Courtesy Ryan Aeronautical Co.)

punch so that deep draws can be made with very fine side detail.

The punches used in all of these forming methods are usually made from "Kirksite", a zinc-base casting alloy. If only a few parts are required and the pressure is not too high, the punches can be made from plastic, impregnated fiber or hardwood. For long runs or high-pressure forming, brass, aluminum, cast iron or steel is used.

Stretch forming is used to produce large parts of comparatively simple contours such as panels, cowlings and fairings. The first of these stretch presses were simple rams which were raised between fixed parallel jaws that held the sheet or blank taut. A punch, or form block, was mounted on the ram. As the punch rose the sheet was wrapped around it and assumed its contour. A modified unit has movable jaws so that the blank can be prestretched beyond its yield point before the punch is raised so that the amount of springback can be reduced. Punches are made of wood or plastic so that considerable savings in tooling for short runs are realized.

Several improved versions of this process have been developed and its utility has broadened to include forming of bars and extrusions in addition to sheet. The jaws are free to move both horizontally and vertically so they can be lowered as the ram is raised between them.

In another kind of press, the punch is horizontal and may be either stationary or movable. Either one or both of the jaws is rotated to stretch and wrap the part around the die. Some of this equipment can form sections a full 360° or even make continuous spirals. A radial draw former produced by Cyril Bath Co. is one of the latter but in addition it has a third movable arm which presses a "traversing shoe" against the outer edge of the part. The shoe acts like a female die and permits deeper and much more accurate contours to be formed. The dies used in stretch-wrap forming are usually made of steel or cast iron to withstand the high forming pressure developed.

The light metals, aluminum and magnesium, are the most used for aircraft parts and although they are formed by the same processes, there are some differences in the tchniques employed. Magnesium alloys are usually formed warm because their formability is low at room temperature and increases with temperature to an optimum at about 600° F. When rubber is used in the forming operation, the maximum metal temperature is held below 450° F. and special heat resistant rubber must be used. The blank and die are usually preheated together in an oven and transferred to the press for forming. Zinc-base dies may be used satisfactorily but cast aluminum or magnesium alloy dies are generally recommended.

The common high-strength aluminum alloys whose strength is developed by precipitation hardening represent the other extreme in temperature control for forming. They are usually drawn in the solution treated condition and then age hardened after forming. Most of the alloys age harden slightly at room temperature so that they must be formed as soon after solution treatment as possible. Aging may be retarded by keeping the sheet at a low temperature, about –20° F., in a refrigerated container until the drawing operation can be performed.

The cost of both the tooling and the labor involved in forming aircraft parts has increased with the increased use of the newer, less ductile materials such as titanium-base and high-temperature alloys. Much development work is currently being sponsored by the aircraft industry to halt this trend, but progress in aircraft design is so rapid that when it is learned how to fabricate the alloys now being used, there will inevitably be newer, tougher materials in production to contend with.

Recent Developments in the Art of Precision Casting

*By NICHOLAS J. GRANT**

Time-tested processes using disposable patterns (wax, plastic or mercury) must compete with others using a thin-walled mold in which the casting solidifies quickly to a fine grain. (E 15)

As RECENTLY as 1940 the now rapidly maturing precision investment casting industry was just emerging from the jewelry, dental and surgical trades. The sudden demand in World War II for vast quantities of supercharger buckets cast of a nonmachinable stellite alloy for the rapidly expanding aircraft program set in motion the broad commercialization of investment castings in ever increasing quantities.

The growth of this industry and a number of the features responsible for the growth are of particular interest. Gross sales in 1953 were about \$95 million; this value rose to about \$106 million in 1954. The latest figures for 1955 indicate about \$135 million. Based on the volume of work done thus far in 1956, it appears that an estimated value of \$150 to 175 million may be expected – an increase of 75% in only four years!

Fig. 1 – Gimbal Weighing 0.52 Lb. Cast of A.I.S.I. 8630 Steel. Wall thickness 0.030 to 0.045 in. Previously sand cast and completely machined. (Courtesy Howard Foundry Co.)

Thus far this growth is based almost entirely on two more or less conventional investment processes – namely, the plaster-bonded silica investments for nonferrous castings, and the several high-temperature bonded silica investments for ferrous and high-temperature alloys. The second process utilizes as the bonding agent tetra-ethyl silicate, or "Nalcoag", or a phosphate. To date, the great bulk of all the precision casting has been with disposable patterns, usually made of wax or plastic but also of frozen mercury. The word "conventional", used above, does not signify in any sense that new techniques have not been tried or that there have not been significant developments and improvements.

Perhaps the best single measure of the maturity of the industry has been the formation of the Investment Casting Institute, a trade association now composed of 31 regular members (metal casting groups) and 17 affiliate members (suppliers and equipment producers). Its activity in the formulation of appropriate and acceptable design and inspection standards will be commented upon later in this article.

Before taking a look at several new precision casting techniques, notable developments within the industry as above delimited are worthy of comment.

Size of Castings – The most frequent size of casting from lost wax or plastic molds has been and still remains from 1 to about 4 oz. – usually

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Fig. 2 – Cross Section of Impeller for Boiler Feed Pump. Type 410 stainless; weighs 23 lb. (Courtesy Misco Precision Casting Co.)

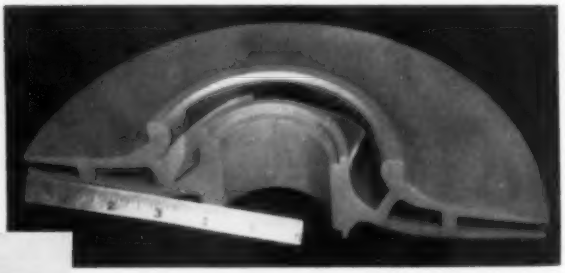


Fig. 3 – 4-Lb. Mounting Bracket for Ram-Jet Engine of Cr-Mo-V Steel, Heat Treated to 180,000 Psi. Ultimate Strength. X-ray inspected for soundness. (Courtesy Engineered Precision Casting Co.)

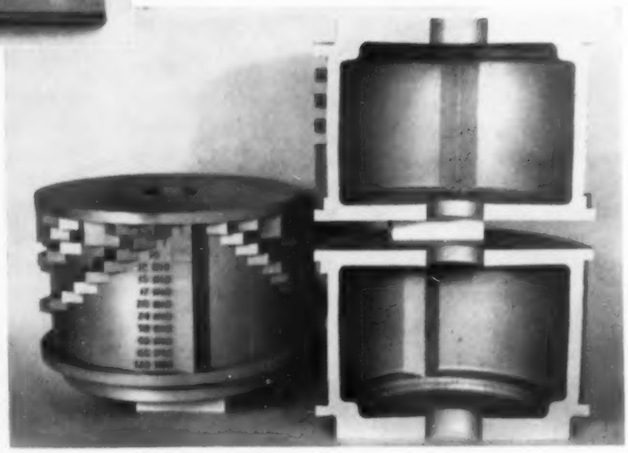


Fig. 4 – Time-Cycle Controller, Exterior and Cross Section. Hollow casting of beryllium copper replaces stack of aluminum alloy disks. (Courtesy Precision Metalsmiths, Inc.)

as a complex but compact body. A typical example of such a small complex part is shown in Fig. 1, a gimbal of alloy steel (A.I.S.I. 8630) weighing 0.5 lb. This is small enough so a fairly large number of pieces can be assembled in one flask, thus resulting in low unit price.

However, the past five years have seen a real departure from this situation in that more and more of the dollar volume is going into castings weighing from 1 to 10 lb. or more, with the larger fraction at 1 to 5 lb. per finished casting. Dimensional accuracy and high surface finish have been maintained at almost the same level as for smaller castings. In fact, as the size of castings increased, the inspection and quality control requirements increased; the principal demand of small precision castings is for high dimensional accuracy, and this has been superceded by strength and ductility requirements in the larger parts.

Figures 2 to 4 show representative castings of the larger types that are being produced at the present time.

Figure 2 shows a cross-sectioned boiler feed pump impeller made of Type 410 stainless steel and weighing 23 lb. The surface finish, as cast, was so good it resulted in 7% greater pump efficiency when compared to the sand-cast product which had been subsequently tooled.

Figure 3 shows a much simpler casting – a mounting bracket for a ram-jet engine made of Timken 17-22 AS alloy (1.2 Cr, 0.5 Mo, 0.25 V), weighing about 4 lb. and heat treated to 180,000 psi. minimum tensile strength. This part had previously been made as a weldment from pieces of machined bar stock. Casting gave the advantages of truer dimensions, X-ray soundness and lower price.

Figure 4 shows a piece in perspective and cross section which almost falls into the category of a "man bites dog" story. It is of beryllium copper and *lighter* than the aluminum piece it replaces! It is a drum whose rotation brings the cams, cast in its surface, in contact with fingers set at required levels so natural gas can be injected into oil wells at required frequency.

(This is a method of pumping oil wells known as the "gas lift".) The drum was originally made from a stack of aluminum disks, bolted together. Cast in beryllium copper as a hollow part, the weight is reduced 40% and machining time cut 75%. Net weight of the casting is 4 lb., 11 oz.

It is obvious that the larger castings are of as complex a shape as the older ones in smaller sizes. It should also be pointed out that the Mercast process has always produced the larger sizes of castings as typified by these three photographs.

One can predict with fair confidence that further growth in the precision investment industry will – to a significant extent – take place via such larger castings, since they constitute a new class of business rather than an expansion of the old field.

These improvements in large castings have been possible primarily through modifications of the conventional investment casting methods. These modifications include a greater use of steel dies, wax injection at higher pressure, and modifications in precoating and investing to produce stronger molds.

Quality, Standards, Specifications – Of particular interest has been the increase in X-ray and surface inspection requirements, due especially to a large quantity of aircraft work.

One of the greatest services of the Investment Casting Institute to its members and customers has been the establishment of standards and specifications. Saddled for many years with wrought alloy specifications, the industry suffered from unrealistic demands placed on its products. Working committees have been established for the following activities, and in most instances firm standards or specifications now exist:

1. Metal specification for precision investment castings.
2. Dimensional tolerances.
3. Physical and nondestructive testing.

These standards will eliminate much confusion and fanciful demands, and will serve as a basis for new processes or for comparison with competitive processes.

In addition, the Institute has undertaken the task of preparing a manual so designers of parts can plan directly for precision castings. Currently many drawings must be modified excessively to convert a part originally designed, for example, for a sand casting or a die casting. Information on dimensional tolerances, section sizes, finish, machining tolerances, and similar essential items will be included.

New Casting Techniques and Processes

For years "precision casting" has been synonymous with "ability to cast alloy compositions which are nonmachinable or poorly machinable or nonforgeable". Furthermore, the cast structure has superior creep resistance and rupture strength compared to analogous forged compositions for high-temperature use. Whereas the iron-base and cobalt-base alloys have been cast without difficulty, the nickel-base alloys such as Inco 700, Waspalloy, M-252, and Udimet 500, have given trouble from their titanium and aluminum content. Even with vacuum melting and casting, forgeability and machinability approach zero with increasing alloy.

On the other hand, recent developments in vacuum melting, vacuum melting and casting, and casting of vacuum-melted alloys in an inert gas atmosphere have extended the precision casting of such alloys to higher alloy content than is permissible for forged products, and this often raises the maximum permissible temperature in operating the part. In fact, vacuum techniques have become standard procedures in many precision casting foundries. Large improvements in properties and soundness – especially freedom from gas pinholes at the surface – have been made by air melting but vacuum casting of aluminum alloys, brasses and bronzes.

Some promise has also been indicated for the casting of titanium in small section sizes. There are, in fact, few alloys which are not being precision cast today, provided the melting point is not much greater than about 3000° F.

Decarburization – A common ailment in the steel foundry – especially when using the hot mold technique in the investment foundry – is the serious decarburization resulting from slow cooling through the temperature range of 2300 to 1300° F. Carbon restoration or recarburization heat treatments are available so this is now no restriction on the casting of steel compositions.

Core Developments – While precision casters have amply demonstrated their ability to cast cored holes of all shapes, particularly as evidenced by intricate wave guide castings and hollow nozzle vanes for jet engines (to mention only two classes of castings), there are frequent instances where the cost of machining and assembling suitable dies becomes prohibitive. This difficulty is being met by water-soluble wax inserts and other intricate coring techniques, which have made large savings in cost and time

and permit freedom of design hitherto unknown.

Control of Structure – Grain size control in precision castings has now been demonstrated. While grain size control is seldom an item in a specification, a number of foundries now control the temperatures of the flask, pattern and hot metal pouring, and so are able to reproduce macrostructures within reasonable limits.

New Processes

The above developments will in all instances be applied to new as well as the old casting processes. All such improvements automatically ease the advent of any new process. Some of these new schemes which have received attention or have been attempted commercially here or abroad are briefly noted below.

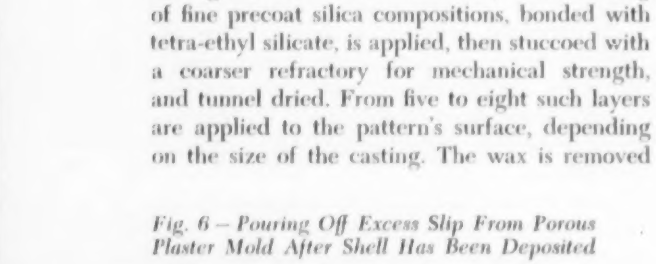
The Investment X Process has been described by J. S. Turnbull in *Proceedings* of the Institute of Mechanical Engineers for 1955, and in *Foundry Trade Journal*, Jan. 13 and 20, 1955. It utilizes a disposable pattern of wax or plastic but avoids the usual investing procedure in producing the mold or flask. Instead, a thin coating of fine precoat silica compositions, bonded with tetra-ethyl silicate, is applied, then stuccoed with a coarser refractory for mechanical strength, and tunnel dried. From five to eight such layers are applied to the pattern's surface, depending on the size of the casting. The wax is removed

Fig. 5 – Typical Three-Piece Shaw Process Mold and Resultant Casting. (Courtesy Shaw Process Development Corp.)

by solution in trichlorethylene at room temperature, thus avoiding cracking the relatively thin investment shell that results from the wax expanding before it melts, as in the usual melting-out technique. This shell, ¼ to ½ in. thick, is then supported in a mass of granular refractory. Wax and solvent are recovered and re-used.

It is reported that considerably larger castings are possible than can be made by the bulk investment process. While the thin shells are undoubtedly less sensitive to a heating rate on receiving the molten metal, the large coefficient of expansion of the silica will certainly result in some difficulty. The thin shells, if cast unsupported, will radiate heat rapidly from the melt and the castings would have a finer grain, and would be less subject to decarburization. Thus far the writer knows of no applications of this English technique in America, although it appears that its advantages should outweigh the anticipated shortcomings.

Fig. 6 – Pouring Off Excess Slip From Porous Plaster Mold After Shell Has Been Deposited



The Shaw Process, as described by A. Dunlop in *Metal Industry* for Oct. 30 and Nov. 6, 1953, was also developed in England. It is not a disposable pattern technique, but instead uses a wood, plastic, plaster or metal pattern – usually a positive pattern – to produce a two-piece or more complex mold. A silica investment bonded with ethyl silicate (other refractories may be used) is poured against a match-plate pattern and time given for the silicic acid gel to form. In this condition, the gel endows the refractory with significant flexibility so the mold can be stripped from patterns with negative draft. The refractory mold-section is immediately fired – it ignites readily from the alcohol in the gel.

Craze cracks are produced during firing but are too fine for metal to penetrate. The fired mold sections are assembled, heated to the desired mold temperature and cast. Figure 5 shows a three-piece mold and the cup-shaped casting. Large castings up to 200 lb. are reported. Surfaces are not as finely smooth as by conventional investment casting or by the Investment-X process because a somewhat coarser sand is required for a stronger mold.

While the process has been operated in England and Switzerland for a number of years, it is relatively new in this country. Its advantages include the use of a permanent pattern without necessity of precoating, ability to handle no-draft or slightly undercut shapes, and extension to larger sizes. On the other hand the master pattern is somewhat expensive, the accuracy of the product is impaired by the split mold, molding is slow and the casting's surface is rougher than a precision investment casting.

Fig. 7 — Turbine Bucket Pressure Cast of Cobalt-Base Alloy Into Hot "Glascast" Shell, Before Any Trimming or Cleaning

The Glascast Process* — Like the above Shaw Process, this works from a match-plate pattern of wood, plastic or metal. Against this pattern the workman casts plaster molds which in turn are used to slip-cast shells. This slip is a water suspension of finely ground (−325 mesh) "Glascast" powder, a glass with ultralow expansion, approximately 97% SiO_2 with 2.5% B_2O_3. This slurry is poured into the box-like mold of porous plaster, and after standing 5 to 10 min. the plaster absorbs most of the water from the slurry in contact with it, and the excess is poured off (Fig. 6). The slip-cast shells, about 0.10 to 0.20 in. thick, are fired at about 1900° F. to a relatively strong shell. After assembling a mold of two or more shells, it is heated to the desired casting temperature (1800° F. for gas turbine alloys). Molds can also be cast cold.

Cobalt alloys can be cast in such preheated molds when the metal is up to 3200° F. without reacting with the molds. The latter have unusually good heat shock resistance and hot strength which permits casting in unsupported shells without danger of cracking. Thin shells mean rapid solidification and fine grain size in the product, also a minimum of decarburization. Vacuum casting would also appear to be practicable because of the small amount of refractory and therefore a low gas content.

Figure 7 shows a typical casting pressure cast, as removed from the mold, before any cleaning has been done. Unusually fine surfaces (40 micro-in. finish or better) have been achieved in great part due to use of finely divided ceramic and to a lack of precoat defects. The disfiguring flash is paper-thin, and is caused by the necessity for wiring the half shells together; cementing them gives so strong a mold that hot tears can occur. This is the source of the main dimensional uncertainty in such parts, which is on the order of ± 0.005 in. per in.

This process is not yet in commercial production, but is currently receiving extensive experimentation and trial runs.

Summary

While these and new processes appear promising for precision metal casting and offer, in particular, opportunity for making still larger castings, the conventional precision investment process continues as the major commercial process. Sufficient improvements in technique have been achieved so it can rapidly grow and expand into the manufacture of larger castings than originally imagined. Certainly, further rapid growth is indicated. Some of the newer processes may well accelerate this trend, especially through production of pieces in the 10 to 200-lb. range.

*See N. J. Grant and R. M. Smith, *American Foundryman*, August 1955, p. 30.

Operating records in a cold metal shop having three 75-ton openhearths and two 75-ton electrics show that the latter can make steel faster and cheaper whenever scrap costs less than pig iron, and the product has equal or better quality. (D 2, D 5, ST)

Electric Versus Openhearth

By *J. E. WILBANKS**

To understand fully any comparison between the operation of cold metal openhearth and electric furnaces, it is necessary first to understand something of the characteristics of each type of furnace, both from an engineering and from a metallurgical standpoint. While the fundamental chemical reactions involved in melting cold charge and refining to carbon steel are identical in both furnaces, we find two radically different approaches to the mechanical problems.

In a cold metal shop the openhearth furnace has many shortcomings and few virtues. It is subject to many variable conditions which affect its operating characteristics. It is badly handicapped by its inherent charging operation. However, it does utilize cheap liquid or gaseous fuels and it will melt reclaimed or pit scrap and other scrap with considerable nonmetallics.

The refractories in an openhearth furnace ordinarily require a considerable amount of maintenance, and because of its bulk and its operating characteristics, refractory cost per ton of ingot is high. On the other hand, the repairs to an electric furnace roof and lining are accomplished in 10% of the time with only one quarter of the labor force required for repairs to an openhearth.

Heat input to the openhearth furnace is limited by variable flame charactristics and inefficient combustion. Even more serious, the heat *absorption* is limited by low temperature differential and relatively large heat losses. At all times the operation of the furnace is subject to human control, and optimum control of operation rarely is attained even when the best instrumentation is installed.

Metallurgically the openhearth is limited by its oxidizing atmosphere which results in high oxygen pickup during melting. Considerable sulphur is also absorbed by the metal as a result of prolonged contact with the flame. These characteristics require large slag volumes and the use of pig iron in the charge, both of which add to the cost of operation.

Production varies throughout the life of each furnace, and drops noticeably toward the end of each campaign. This is in sharp contrast to the performance of an electric furnace which produces steel at a steady rate through the life of each lining.

*Superintendent of Melting, Atlantic Steel Co., Atlanta, Ga. Notes on a talk given before the Southern Metals Conference held in May in Winston-Salem, N. C.

While the electric furnace was developed primarily for the production of expensive alloy steels, modern mechanical improvements and low charging costs have adapted it to the less costly carbon steels. As a result of careful design, most of the undesirable features of the openhearth are completely absent in the modern direct-arc furnace.

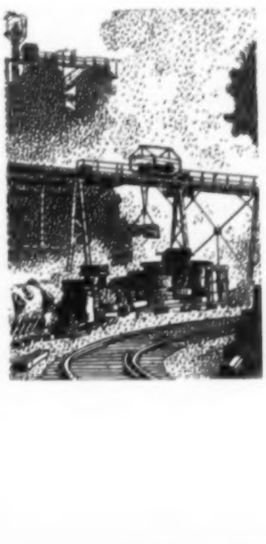
This furnace is designed with a minimum area to its volume, and hence with low heat loss by radiation, it can maintain a metallurgically neutral atmosphere, it produces heat without any contamination from suphur or excess oxygen, and it is mechanically adaptable for rapid charging, easy slag removal, and maintenance of the bottom. Roof changes and major repairs are done quickly with a minimum work force.

The rate of heat input and absorption during the melting period apparently is limited only by the capacity of the furnace transformer, and during the entire operation the heat input is held at peak efficiency by automatic control mechanisms. During the melting period the arc is entirely submerged in cold scrap, but during the refining period heat input is necessarily limited because of furnace refractories which are exposd to direct radiation from the arc.

Since the cold charge is melted, to some extent, from the bottom, the strong boils of the openhearth are absent during the refining period. This results in some difficulty in transferring oxygen from the slag to the metal, particularly in the low-carbon rimming steels. This sometimes results in excessive concentrations of iron oxide in the slag and consequently in higher refractory cost for both furnace and ladle.

Rate of production and furnace availability are both high. Typical months of operation at Atlantic Steel Co. show that an average production of 8.5 tons per hr. is representative of our openhearths, while 16.5 tons per hr. is representative of the electrics. (Both tap 75-ton heats and make the same grades.) Furnace availability approaches 90% in our three-furnace openhearth shop, while the two-furnace electric shop has maintained 95% availability.

The major factors of ingot cost in our cold metal plant are raw materials, fuel and labor. In our particular plant we find that the cost advantages favor the electrics. Under conditions where pig iron and scrap cost about the same there will be very little difference in the cost per ton of steel as made by the two processes.



Quality—In general, after four years of experience in making the same grades of steel in both the openhearth and the electric furnace, we have been able to find no real difference in quality that was not traceable to chemical composition or deoxidation practices.

I believe that furnace builders and steelmakers agree in predicting the continued rapid growth of electric steelmaking. On the basis that the projected 60 million tons of new capacity in the next 15 years will raise our total ingot capacity to about 185 million tons, electric ingots will probably rise to about 15% of total ingot capacity, as compared to about 8.5% now. I question whether we will see any more openhearth shops built for cold charging, as would be the case in the nonintegrated plant.

In summation, I would like to pin-point what we believe are the numerous clean-cut advantages in favor of electric furnaces.

1. Cost of the initial installations should be 40% less than for equivalent openhearth capacity.
2. Less space is required; electrics can be built for expanding capacity where available space is limited.
3. Electrics can be operated by either the single-slag or the double-slag process.
4. Flexibility in operation—electrics can be operated around the clock or any part of the time as needed.
5. The high thermal efficiency of the electric arc permits the operator to control the temperature more closely without any danger from sulphur-bearing liquid fuels.
6. An electric furnace can use most types of scrap at a lower preparation cost.
7. An electric furnace plant is one way to combat centralization of the steel industry in the hands of a few large corporations.
8. Only by electric furnaces can the operator obtain a flexible balance in an integrated plant.
9. In making alloy and special steels, the electric has the advantage due to better alloy recovery.
10. Electric furnaces can do everything openhearth furnaces can do and do a better job making quality steel.

In consideration of the fact that, in the last 20 years, electric furnace capacity has increased 925% compared with 61% for openhearth capacity, it is certain that the electrics have a very bright future in the steelmaking industry — and especially in cold metal plants.

Metal Powder Rolling– a New Fabrication Technique

*By SAMUEL STORCHHEIM**

Wartime work in Germany on driving bands for artillery shells has been extended in America to 18-8 stainless steel and other powder metal combinations for manufacturing fuel elements for atomic power reactors. (H 14, Fe, SS, Al)

A FASCINATING and relatively new metallurgical fabrication process is the rolling of metal powder into finished strip. While it is still in the state of experimental development in America, its potential is as important as other newcomers, such as extrusion and co-extrusion of metal powders, hot pressing of powders and – to go into other branches of the metals industry – continuous casting and static pressure welding.

Rolling of powder into strip is by no means new. It was first studied in the experimental department of the German electrical firm of Siemans and Halske and actually patented in 1902. A patent was issued in 1938 to the American, Charles Hardy, concerning the rolling of metal powders transported through the rolls on a carrier.

Apparently nothing much was done with the idea until World War II, when the Germans tried it as a means of consolidating iron powder into rotating bands for projectiles. B. M. Pearson reviewed these attempts in *Iron Age*, Feb. 1 and 15, 1951, and one of the leading German investigators, Gerhard Naeser, described his work before the 4th International Mechanical Engineering Congress in Stockholm, Sweden, in June 1952. His data about this will be freely quoted in the present contribution.

Returning home from the Stockholm meeting, Henry H. Hausner interested the Sylvania Electric Products Corp. and the U.S. Atomic Energy Commission in the possibilities, and it was the writer's good fortune to be involved directly in the work under an A.E.C. contract. Since many of the metals used in atomic reactors, as well as the fissionable or fertile metals thorium, uranium and plutonium, are reduced from purified chemical compounds in powder form, the first fabrication step is usually one of consolidation. The plan of rolling such powders – either pure or when mixed with others in desirable alloying proportions – appeared to have considerable advantages over those exisiting methods requiring heat and associated dangers of contamination by surroundings and containers.

At Sylvania's laboratories at Bayside, N. Y., we did some of the first rolling of hard metal powders, particularly of 18-8 stainless steel, but we also pioneered the rolling of aluminum powders. Considerable information on the formation of 18-8 stainless strip was published by the

*Assistant Chief of Materials Section, Glenn L. Martin Co., Baltimore, Md. The author wishes to record his gratitude for help in preparing this article to Bernard Sprissler and Walter Marz, engineer and engineering laboratory assistant, respectively.

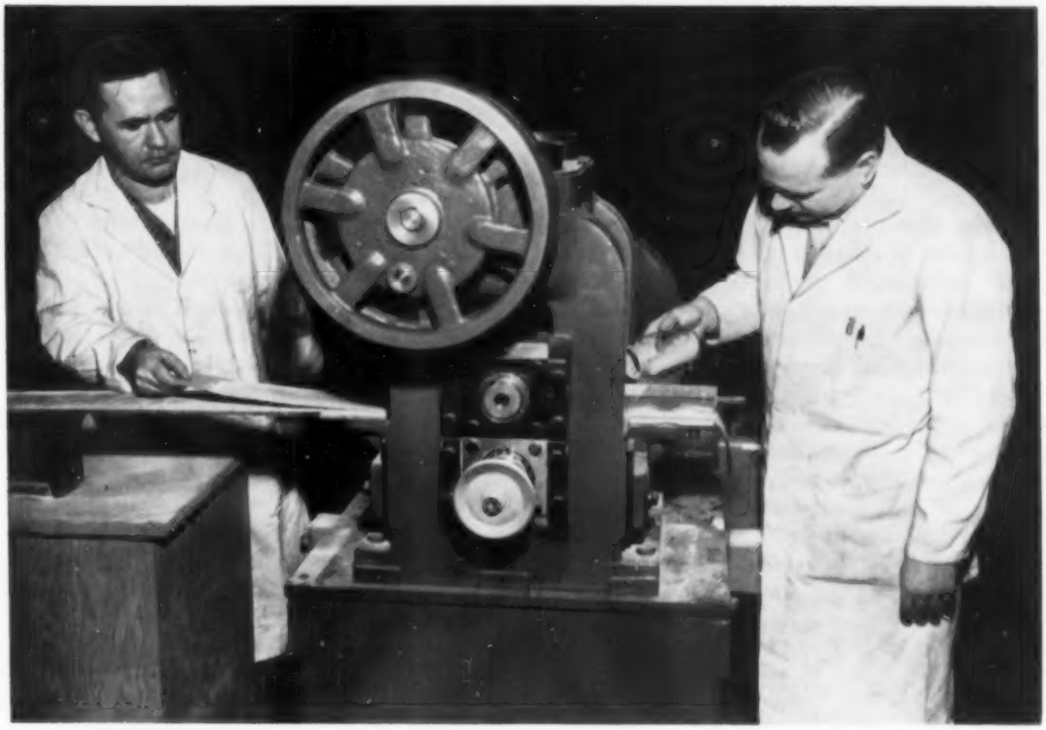


Fig. 1 – Horizontal-Feed Powder Rolling in the Laboratory, Using a Paper Strip for a Carrier

present writer with J. Nylin and B. Sprissler as co-authors in *Sylvania Techniologist*, April 1955, and this document is also quoted freely later in the present article. Following these disclosures, the process has been picked up by several other laboratories and plants, including the Whitaker Metals Corp., in North Kansas City, Mo., where reclaimed copper scrap in powder form is rolled into strip. The Glenn L. Martin Co. is studying the process and is applying this new technique to the production of nuclear fuel elements. In addition, rolling of nickel powder is being done in Great Britain as a method of handling fine metal produced during the decomposition of nickel carbonyl.

Aims to Be Achieved

Well, why do we want to roll powders? What are the advantages?

One prime advantage – which applies to all powder metallurgical methods where the part is compacted cold and never heat treated under conditions which cause excessive grain growth – is that unique properties can be obtained with very fine grains. High mechanical strength is frequently associated with such compacts as they approach theoretical density and a vanishing amount of porosity. Second, it has been observed that such rolled sheets have no crystallographic orientation, that is, the metal grains are randomly oriented. This is potentially applicable to forming uranium sheet for reactor elements, as oriented uranium usually grows to a damaging degree under irradiation. Third, the British have shown that purer nickel sheet can be obtained this way than by conventional techniques. Fourth, powder rolling does not require such large capital investments in equipment; that is, much of the apparatus needed for melting, casting, hot rolling ingots and then cold rolling slabs of metals into thin sheets is done away with. Fifth, a metal strip can be clad on one or both sides by using it as a carrier of the chosen powder through the rolls. Sixth, a larger percentage of any scrap material reclaimed in powder form can be made into strip, rod, and wire more cheaply than by conventional techniques. Finally, there is the advantage found in the rolling of complex core materials for fuel elements, such as aluminum plus uranium dioxide. In cold working compacts made by conventional means down to finish size, it has been found that the uranium oxide will

"stringer" – that is, line up and possibly fracture. This is considered quite detrimental for subsequent use in reactors. However, by rolling powders into finished strip we have observed that the oxide particles do not stringer but remain randomly oriented and uniformly dispersed. (Uranium dioxide and aluminum are of course not the only useful combinations.)

It is, of course, necessary to have some ductility in the metal powders being used; otherwise, no plastic deformation and subsequent interlocking of the particles would occur. Actually, rolling has been used for pulverizing brittle materials.

As noted by Dr. Hausner in his review of the development of powder metallurgy in *Metal Progress* for September 1955, powder metal products are no longer limited in dimensions by die size or press capacity. "Powder rolling is already producing long metallic bands or sheets, either of high density or of controlled porosity, characterized by a randomly oriented fine-grained structure. Copper, brass, iron or stainless steel sheets of any desired length can now be produced at low cost."

If a strip of metal – say mild steel – is to be clad with a thin layer of another, the metal strip would obviously be the carrier.

Figure 2 is a schematic representation of the vertical arrangement. The hopper shown may be eliminated and the powder merely dumped in the channel between the rotating rolls. This is known as a "heavy powder feed". When the rolls turn they drag the powder through and press it to form strip. This has an advantage over conventional powder metallurgy techniques wherein the powder is pressed in a restrained die, and the pressure approaches the hydrostatic in nature. In powder rolling we only press in one direction, that is, *push* the powders together as they flow between the rolls and thus they have one degree of freedom.

When a hopper is installed, as diagrammed in Fig. 2, the powder no longer is fed between the rolls; rather, the latter pinch it and carry it through. The design of the discharge slot is important, and is shown in detail. Note that a straight chute extends from the bottom through which the powders must drop. (A vibrator is a

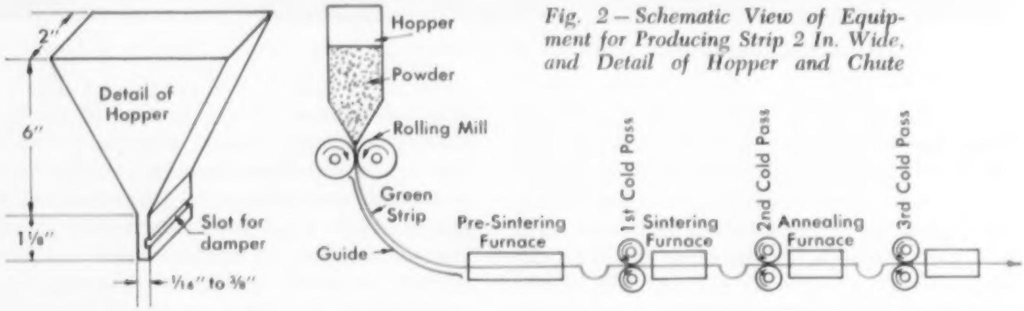


Fig. 2 – Schematic View of Equipment for Producing Strip 2 In. Wide, and Detail of Hopper and Chute

necessary adjunct if the powders are not free-flowing.) It is quite important that this straight drop be included in the hopper feed, particularly when cladding metals. We found that the clads can be controlled quite precisely if the drop of powder is vertical. If it is at an angle, then control of the thickness of the clad around the core materials is very difficult.

The sketch shows a possible sequence of operations. The powder comes between the rolls in a uniform thin stream, the green strip is continuously fed into the first furnace for a preliminary sinter, is cooled, cold rolled, furnace sintered, again cold rolled, furnace annealed, and given a final rolling for size or temper.

Certain variations may be made from this continuous sequence of Fig. 2. There is the possibility of coiling the green strip and then batch

Techniques of Powder Rolling

In the rolling of powder, the rolls may be set one directly above the other so the strip emerges horizontally, as shown in Fig. 1, or they may be set side by side so the strip emerges vertically downward, as diagrammed in Fig. 2. In Fig. 1, showing horizontal feeding, the operator is pouring powder on a carrier (in this case a strip of paper) and the other operator is acting more or less as a tension guide. At the Glenn L. Martin Co. we now use rolls of accounting paper as the carrier, load it from a hopper, regulate the amount by an adjustable lip and have a take-up reel on the opposite side of the mill. The metal strip can either be peeled off the carrier or else the paper can be burned off during sintering.

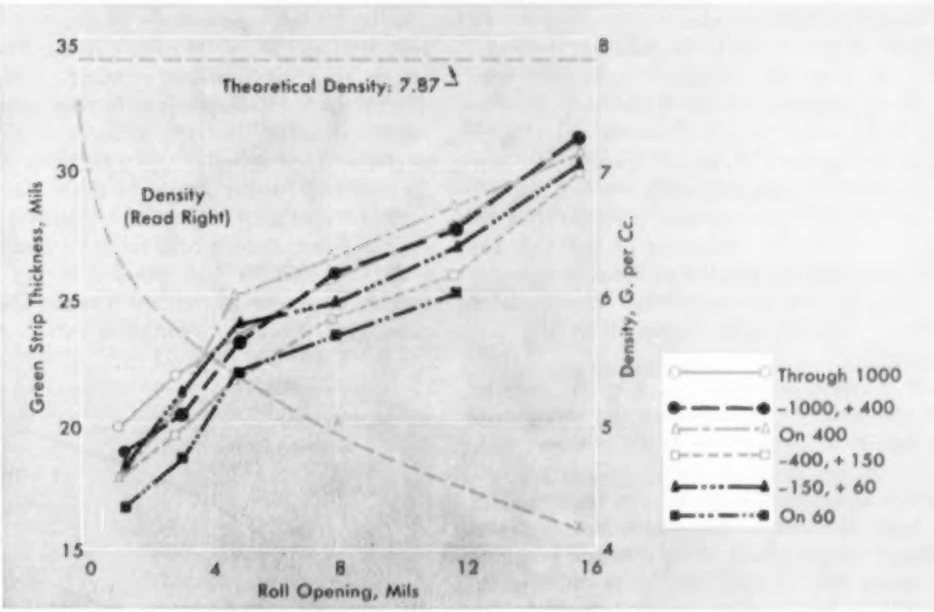


Fig. 3 – Particle Size of Iron Powder Has Relatively Little Influence on Thickness of Green Strip. Its density is largely affected by roll opening

sintering it, this to be followed by cold rolling and the other operations indicated. It is interesting to note that little if any mention has been made in the literature of the possibility of hot rolling the green strip. We have found this not only to be feasible, but absolutely necessary when working with aluminum powder. Hot rolling of green strip also avoids long sintering times, and permits much higher reductions of strip thickness before annealing becomes necessary.

Some information is available concerning the effect of mechanical variables on the thickness of the green strip. For example, take the following data on thickness of strip made from aluminum powder, fed vertically and fed horizontally, as the roll opening varies:

Roll Opening	Green Strip Vertical	Thickness Horizontal
10 mils	17.2 mils	13.0 mils
15	21.0	17.8
20	25.0	22.3
25	29.0	27.0

The differences are not wholly due to variable springback in the rolls and housings. While there is not too great a difference in thickness for the same roll opening, vertical feeding appears to crowd more metal between the rolls, and the "oversize" is greater for close settings than for more open ones. Experiments on iron powder by Naeser in Germany show that this effect is slightly exaggerated as roll diameter increases.

Likewise speed of rolling has an influence – the faster the rolls are rotating the thinner the green strip. Specifically, our experiments on 18-8 powders at Bayside with rolls set close together (zero opening) and fed from a hopper with 1/16-in. chute produced a green strip 15.7 mils thick when the rolls were driven at 10 rpm., and only 8.2 mils when at 40 rpm.

The distance between bottom of hopper chute and the rolls can vary between zero and 0.5 in. without making any difference in the green strip thickness when the rolls are running slowly (10 rpm.). At higher speeds (30 rpm.) raising the hopper the above distance *reduced* the green strip thickness about 15%.

Another variable in hopper feeding is the width of the opening. Here again, this item has little effect when the chute is close to the rolls and the rolls are operating at zero opening and at low speed; the green strip is about 15 mils thick. With higher speeds (40 rpm.) the wider hopper openings, feeding larger amounts of powder into close-set rolls, give much thicker green strip, less constant in dimension:

Hopper Opening	Green Strip Thickness Min.	Average	Max.
1/16 in.		8.5 mils	
3/16	11.3	12.1	12.9
3/8	15.0	20.0	25.0

Average particle size also has an effect on the thickness of green strip for various roll openings. Figure 3 from the German work with iron powder of various sizes shows that there is relatively little change in strip thickness with change in particle size for a given roll opening and that the particles through 400 mesh produce slightly thicker strip than the coarse particles (on 60 mesh). Under the conditions of the German work, especially the rigidity of the mill, one can generalize in the statement that iron powder produces strip 17 mils thicker than the roll opening.

Roll opening, however, has a large influence on the density. At zero opening the green strip with density of 7.5 g. per cc. is 95% of theoretical, but the thicker strips produced with larger roll openings are much less tightly compacted. The very high densities at the smaller openings are attributed to springback of the rolls and housing. This green strip of iron powder is quite weak so it has to be carefully handled through the presintering furnace.

Stainless Steel Strip

Stainless steel appears to be a good alloy for protecting or cladding the uranium in an "intermediate" reactor – that is, one wherein the neutrons necessary for the chain reaction are only partially slowed down. The uranium or other fissionable material inside each of these "fuel elements" may be fabricated into the element by powder metallurgical processes, and it therefore appeared desirable to study carefully the manufacture of 18-8 strip from alloy powders, its subsequent mechanical properties and its stability in contact with water or other coolant at high temperature and under intense radiation. Because of the heat generated by atomic fissioning in the center of these elements, the problem of heat transfer is also important. Obviously, if the core and protecting sheath could be made almost simultaneously by powder metallurgy methods, we would have an ideal joint for the transmission of heat.

We found that irrespective of speed of the rolls – 13, 30 or 40 rpm. – the green strip was about 30 mils thicker than the roll openings when tightly or narrowly set, and proportionately less to about 20 mils thicker than the opening when the rolls were widely set – say 30 mils apart. However, there was a strong influence on quality. At the slow speed of 13 rpm. we got uniform and strong strip up to 30-mil roll opening (producing green strip 50 mils thick), but on wider openings a large percentage of the powder was lost. Roll speeds of 30 rpm. gave uniform and strong strip up to 20-mil opening (green strip 47 mils thick). Roll speeds of 40 rpm. apparently were too high; the strip was weak along its center and not cohesive when the rolls were set 25 mils and further apart. In other words, the range for obtaining uniform strong strip is greater for the slower speeds than for the faster speeds.

As is shown for iron powder in Fig. 3, the density decreases as the roll opening increases, although not nearly to the same extent. At zero opening the green density averages 6.8 g. per cc. (about 85% of theoretical), dropping rapidly to about 6.5 g. per cc. at roll openings of 5 mils and then more gradually to about 6.0 g. per cc. at roll openings of 25 mils. Contrary to the appearance of green strip rolled at the higher speeds, as mentioned above, 40 rpm. gave somewhat higher densities than slower speeds.

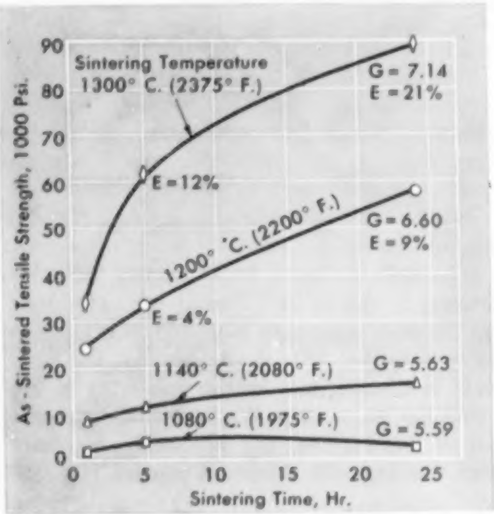


Fig. 4 – Effect of Sintering in Hydrogen at Various Temperatures on the Tensile Strength and Elongation of 18-8 Green Strip. Eventual densities in g. per cc. are noted at the ends of the curves

The work summarized above on iron and 18-8 was based on powder dumped on the rolls of a mill set to discharge in a vertical plane. When a hopper and chute, such as shown in Fig. 2, is used, results are somewhat different. Without going into much detail, which would be out of place in this general statement, it may be said that thickness of green strip increases much as described above with increase in roll openings

at roll speeds up to 30 rpm. (The same effect was noted, although to a less degree, on an aluminum alloy containing 1% nickel and 0.3% iron.) Thus, regardless of the metal powder, the indication is that green strip thickness is always considerably larger than the roll opening.

However, when the hopper has a ⅜-in. opening the 18-8 green strip density *increases* from about 5.7 g. per cc. at zero roll opening to about 6.9 at 4 or 5-mil roll opening (producing a 35-mil green strip at speeds up to 30 rpm.). Thus, the allowable roll opening that can be used for verticle feeding by hopper is considerably less than for the dump-type feed – a maximum of 7 mils versus 30 mils, respectively.

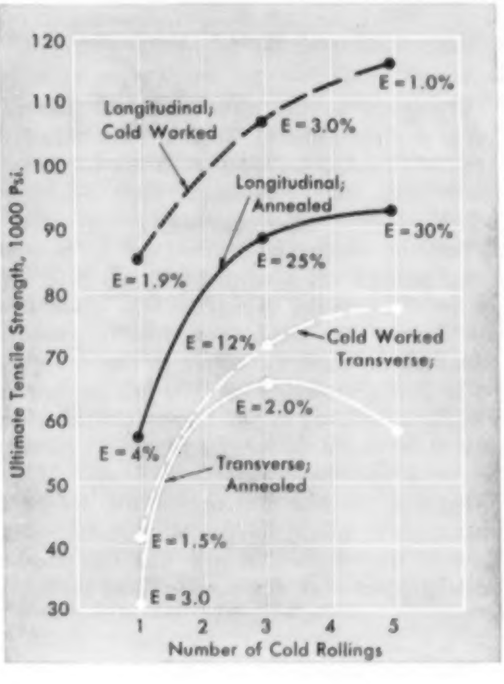


Fig. 5 – Tensile Strength and Elongation of Sintered 18-8 Green Strip After Various Programs of Cold Working and Annealing. Properties are much better in the longitudinal than in the transverse direction

Sintering and Hot Rolling

Green strip is weak. In a production line, such as sketched in Fig. 2, the first sintering may be quite short – on the order of 1 min. to consolidate and strengthen the metal so that it can easily be handled for further rolling. Dr. Naeser's report on the German work indicates that green strip of iron, having a tensile strength of only 1300 psi., can be strengthened to 4500 psi. by short-time heating at 1100° C. (2000° F.) and to 5250 psi. at 1200° C. (2200° F.) Weak though this may appear to be, it was good material for cold rolling. Five passes brought the strip into such condition that its tensile strength was 45,000 psi. and its elongation 25%.

We could get good strength by sintering stainless steel in hydrogen at high temperatures for say 24 hr. The green strip itself has considerable strength and ductility and can easily be coiled and batch sintered. It was prepared in the following way:

Average grain size of powder	–325 mesh
Hopper slot opening	⅜ in.
Roll diameter	6 in.
Speed of rolls	13 rpm.
Opening between rolls	0
Thickness of green strip	16 mils
Density	5.5 g. per cc.

Figure 4 shows the effect of sintering time and temperature in hydrogen on this stainless steel strip. We see that with increasing temperatures and times to 24 hr. the tensile strength increases as soon as 1200° C. (2200° F.) is reached, and there is a very sharp increase in strength with a maximum of over 90,000 psi. at 1300° C. (2375° F.) for 24 hr. Density also increases at these higher temperatures, as noted by the figures at the ends of the curves. Elongations before sintering and after all sintering up to 2080° F. were 1% or less; elongations after higher sinterings were more satisfactory, reaching 21% at the maximum. At highest strength and elongation the density is 7.14 g. per cc. or 90% of theoretical. Remember this is the green strip, as sintered, without subsequent working.

Some data on hot rolling in air at 600° C. (1100° F.) were accumulated on aluminum with 1% nickel and 0.3% iron powder added. Two passes, with rolls set at zero opening, consolidate the green strip of density 1.55 g. per cc. to 2.64, which is 96% of theoretical. A homogenizing heat treatment at 1100° F. for 2 hr. in hydrogen then produced metal of 2.76 sp. gr., slightly denser than theoretical as figured by the method of mixtures. This can be explained by the formation of a compound $NiAl_3$ which has a greater density than the mixed crystals, and there is enough of this $NiAl_3$ intermetallic formed in the strip to increase the over-all density of the strip beyond the theoretical 100%.

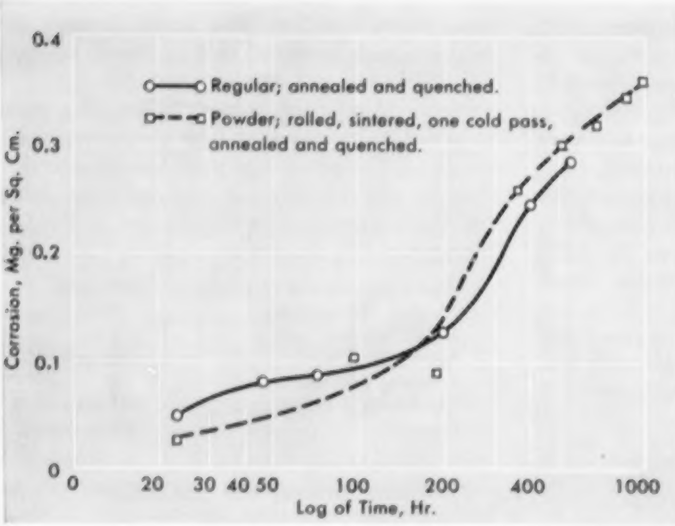


Fig. 6 – Comparative Losses by Corrosion in Water at 680° F. of Commercial and Powder Metal 18-8

Cold Rolling Sintered 18-8 Strip

Figure 5 shows the effect of cold rolling sintered green strip of 18-8. The green strip was prepared under the more-or-less optimum conditions listed above and then sintered at 2375° F. for 24 hr. Following this, samples were cold rolled one, three or five passes, the rolls being set at zero roll opening for each pass. Samples were then tested in both longitudinal and transverse directions as cold rolled and others after annealing in hydrogen at 2375° F. for 2 hr.

It will be observed that there is a considerable difference in properties of the strips taken in the two directions. The maximum tensile strength attained is 115,000 for longitudinal strips and only about 80,000 for the transverse sections. In both directions the strength increased rapidly with increasing number of cold roll passes.

When the samples are annealed after being cold rolled, the strengths rise and level off for both longitudinal and transverse directions. Transverse strength may be impaired by further cold working prior to annealing. Here we again see that the longitudinal strengths are greater than the transverse for the same number of cold roll passes – about 88,000 versus 66,000 psi. at three passes. Cold worked longitudinal specimens have low elongation; after annealing the elongation attains a maximum value of 30%. Elongation is also considerably lower for the transverse specimens than for the longitudinal ones.

Finally, after making satisfactory 18-8 stainless steel strip from powder, we determined its corrosion resistance in water at 680° F. (Fig. 6).

The green powder metal strip was sintered, given one reduction in the cold rolls, annealed at 2375° F. and quenched. Comparison test pieces were made from commercial Type 302 strip, which was also similarly annealed and quenched.

Both the commercial material and the powder metal product lost somewhat less than 0.100 mg. of metal per sq.cm. of surface area in the first 200 hr. but then this state of relative passivity was broken. While the curves in Fig. 6 appear to be rising steadily after 1000 hr., the rate is steadily decreasing as will be appreciated when it is remembered that the horizontal coordinates are on a logarithmic scale.

Perhaps the real evidence of the curves is that there is little difference in corrosion resistance of the commercial strip and the powder metal product when immersed in water at 680° F.

Conclusion

This now concludes the major points which were to be discussed. The writer strongly feels that powder rolling is one of the most fascinating and unique of the modern fabrication processes. It has a great potential from all the advantages it offers. We are just now starting to get into the areas of greater promise – namely, use for nuclear fuels. In the very near future, the quantities of metal powders that are rolled may be fairly large, on the order of about 5% or more of the total market of materials for a particular alloy system. This will mean that powder rolling as a major fabrication technique will have to receive due consideration from many metal manufacturers.

Radiation Damage to Unborn Generations

Six committees of eminent scientists have reported to the National Academy of Sciences their studies of the effect of high-energy gamma radiation on genetics, pathology, weather and food supplies. A summary has been published, from which the following extracts supplement the article on "Genetic Effects of Atom Bombs" in *Metal Progress*, October, 1955.

Every cell in the human body (and in every other living organism) contains a collection of tiny units called "genes" which determine the characteristics the individual is born with. Each person gets his genes from his parents, who got them from theirs, and so on. They come in pairs, one gene of each pair is inherited from the father and one from the mother.

Gene pairs are acquired thus: Sperm and egg cells have single sets of genes rather than pairs. When a sperm and egg unite to form the first cell of a new embryo, there is a new double set, half coming from the father and half from the mother. As the embryo develops, this set is duplicated over and over again so that every cell in the body of the fully developed infant has an essentially identical set of genes.

[It is believed that genes from the mother and from the father are paired, and that one is usually "dominant", although not overpowering, while the other is "recessive", although it retains some influence. In the child the result is a compromise. Thus the continual reshuffling of a fairly limited number of genes leads to the almost infinite variations, person to person.]

Every so often a gene in the sperm or egg cells changes or "mutates", in a way as yet mysterious, and the characteristic of the organism which it controls in the offspring is altered. Heat, certain chemicals, and radiation will do it. Genes in sperm and egg cells are especially vulnerable to gamma and X-radiation, and once changed, the new form is passed on as faithfully as the old one was. The processes of life are so delicately balanced that any departure from the established order of things at the cellular level is overwhelmingly likely to be for the worse. Mutations almost invariably harm the organism in which they occur, even though evolution results from a sequence of rare mutations, each of which produced an organism slightly better equipped than its ancestors to deal with the environment. But the exceptions merely prove the rule: *Most mutations in reproductive cells are harmful.* Also, since mutant genes are usually "recessive", the harm may not be apparent for several generations. On the average, a detrimental mutation, no matter how small its harmful effect, will in the long run tip the scales against some descendant who carries this mutation, causing his premature death or his failure to produce the normal number of offspring. In this way harmful mutations are eventually eliminated from the population.

Speaking in broadest generalities, the human race at present carries a supply of recessive genes and has constantly been absorbing mutants from heat, absorbed chemical compounds, and cosmic and other natural radiation. The total supply represents a balance between the tendency of old mutants to eliminate themselves, and the tendency of new ones to appear. *Any* additional radiation – as from X-ray examinations or atomic bomb fallout – will produce a corresponding number of additional mutations, and this will *almost always* tip the scales in the wrong direction. It follows, therefore, that we ought to keep all our exposure to radiation as low as possible.

A population that is exposed, generation after generation, to an increased amount of radiation will experience a rising death rate and a falling birth rate because of harmful mutations, until a new equilibrium is established between the increased rates of mutation and elimination. If, in this process, the death rate comes to exceed the birth rate, the population will decline and eventually perish. At present we are extremely uncertain about the level of this fatal threshold.

[Finally the scientists estimate that the natural radiation with which the human race is in balance totals about 4.3 roentgens from inception to age 30, at which time half of the children are born. For the present generation this will be increased by 0.5 roentgen by fallout from atomic explosions. A much larger increment – 3.0 roentgens – comes to the average civilized man in his first 30 years from X-rays. It is understandable, therefore, that geneticists are much disturbed over this new state of affairs. During evolutionary processes we have adjusted ourselves to 4.3 roentgens, and now we suddenly jump this up to 7.8 roentgens, nearly double. It is to be expected that our present "defectives" will eventually be doubled to about four out of every hundred, and "extinction of the mutant genes is accomplished only through tragedy".]

Did you know that only 10% of the aluminum made in the U.S. in 1955 went into aircraft, or that the largest single use of magnesium is as an alloying metal? Innumerable postwar applications have resulted from wartime experience. (T general, Al, Mg)

The Light Metals in American Economy

*By FRANCIS C. FRARY**

First let me define "light metals", for the purposes of this presentation, as magnesium and aluminum. They have other characteristics in addition to lightness: They are the only two metals in general use that are produced electrolytically. They also have strength and stability under atmospheric influences.

I will first consider, briefly, magnesium.

Magnesium—The total production of magnesium in the United States in 1955 was 61,135 net tons. Its largest single use still is as an alloying element in the production of certain aluminum-base alloys, and the steadily increasing tonnage of such alloys has naturally increased its consumption. A considerable and increasing amount of pure magnesium is also consumed in the production of titanium by the Kroll process, and the reduction of metals used in the atomic energy program, such as beryllium, thorium, uranium and plutonium.

A number of magnesium-base alloys are used for structural purposes. Their chief advantage is their greater stiffness per unit weight, especially where compression loads are important, and their high strength per unit weight in the form of castings. In aircraft, they are chiefly used in engine housings, landing wheels, gear covers and cases, brackets, and small fuselage castings that are not highly stressed. In one modern airplane, which required a very strong structural framework, magnesium alloy sheet was used for the fuselage skin and the trailing edge of the wing, where stresses were low and stiffness important. The total amount of wrought magnesium products has grown rapidly in recent years and is now about as great as that of cast magnesium forms.

Aluminum

World production and consumption of aluminum have multiplied more than three-fold in the past ten years, and increased producing and fabricating capacity is being planned and constructed in many places. In the United States, with the largest primary aluminum-producing capacity in the world (1,500,000 tons) we are still unable to make enough to supply our own needs; last year we imported about 200,000 tons from Canada, in addition to reclaiming a large tonnage of secondary metal. It seems interesting, therefore, to look briefly at the different industries in which this tremendous American demand has developed.

Architecture—Last year the architectural field consumed about 20% of the total primary metal—about twice as much as was used in aircraft. Aluminum-clad buildings, ranging all the way from small offices to skyscrapers, have sprung into popularity within the last five years. The tallest one is the 39-story Republic National Bank Building in Dallas, Tex., containing about 750 tons of aluminum, two-thirds of which is in the exterior wall surface. The low labor cost for installation of prefabricated sections makes such

*From 1918 to 1952 Director of Research for Aluminum Co. of America; now retired. This paper was read at the Third International Light Metal Congress in Leoben, Austria, on June 7, 1956.

a wall competitive with stone or a good quality of brick; very pleasing architectural effects may also be produced. More than 200 aluminum-clad multistory buildings have been built or are under construction, and the additional floor space provided by the thinner outside wall (with good insulation) is valuable to the owner. For factory building walls, two layers of corrugated sheet with a pad of glass wool between them provide low cost and normal thermal insulation.

The aluminum windowframe was one of the early architectural innovations, pioneered in the building of the Alcoa Research Laboratories in 1929. Now between 50 and 55% of all window frames in commercial buildings and 24% of those in new residences are of aluminum. The cost is less than that of bronze and only 15 to 20% more than unpainted steel frames, and the cost of painting and repainting the steel frames soon makes them more expensive than aluminum which needs no maintenance. A variety of miscellaneous items (such as 1,500,000 ft. of extruded coping to cap brick walls, probably weighing about 1500 tons, in 1955), require a large tonnage. Aluminum fins on the pipes carrying heating or cooling fluids for heating and cooling air in buildings and dwellings consumed last year more than 3000 tons. Sheet aluminum ventilating ducts compete in economy with galvanized steel.

The transportation industry consumed nearly 20% of the total primary aluminum in airplanes, private automobiles, trucks, buses, trains and marine craft. About half was used in aircraft, nearly as much in highway transportation, and, roughly, 4% for railroad and marine equipment.

Aircraft (especially military and naval aircraft) are getting much larger and faster. Simultaneously the wings are much thinner. This has required the production of large plates of strong aluminum alloy, tapering in thickness from one end to the other, as well as sheets having integral stiffening ribs. A special mill turns out many plates 60 in. wide by 26 ft. long, tapering from ⅝ to ⅛ in. in thickness, and is capable of rolling such plates up to a width of nearly 100 in. The ribbed sheets are extruded on a 14,000-ton extrusion press, capable of producing a 2500-lb. extrusion 100 ft. long. Such a ribbed sheet may be up to 38 in. wide; a common size is 24 in. wide and ⅛ in. thick, with ribs ⅛ in. thick and 1½ to 2 in. wide, spaced 2 to 4 in. apart. For certain types of planes, where the stiffening ribs converge instead of being parallel, such an item would be machined out of heavy plate, 2 to 2½ in. thick. Powerful stretching machines, able to stretch pieces of strong alloy having a cross section up to 60 to 70 sq.in., are used to straighten heat treated sections and relieve internal strains in such plate before machining operations.

Forged Aluminum Wheel Centers for Cadillacs Come Hot From the Dies

Automobiles—In 1955, the automobile industry in the United States produced nearly 8,000,000 passenger automobiles, containing from 10.8 to 191.6 lb. of aluminum each. The average was 29.6 lb. per car, giving a total aluminum consumption of about 118,000 tons. Die castings and permanent mold castings still make up the most of this. All passenger cars and most trucks have aluminum pistons cast in permanent molds, and a large proportion of the passenger cars have automatic transmissions with aluminum rotors and stators (mostly cast by the plaster process). One make of passenger car and some trucks use forged aluminum wheels, and the use of aluminum trim is growing.

Radiators with aluminum fins soldered onto brass tubing are in successful experimental use, and preliminary experiments are being carried out on all-aluminum radiators. A transition to aluminum would relieve a lot of pressure on the scarce copper supplies.

The body and framework of two out of every three of the large van-type trailer trucks are of aluminum, and its advantages in tank trucks are generally accepted. Haulage of various liquids and dry powders in bulk is increasing the demand for such aluminum tanks. The possibility of easy clean-up, so the same unit can haul fuel oil at one season of the year and ammonium nitrate fertililzer or other liquids at others, is attractive. More and more aluminum bodies are being put on medium-sized and smaller trucks as experience proves their economic advantages. Passenger buses contain from 1 to 3 tons of aluminum each, depending on their size. Thus, the total amount of aluminum used in the United States in 1955 in the automotive industry was nearly 200,000 tons (a part of this being secondary metal).

Railroads – In the railroad industry, 35 Pullman sleeping cars with aluminum superstructure were built for the Union Pacific Railroad, and construction was begun on two light trains, all-aluminum, similar to those recently built in Germany. The first of these was delivered to the New York Central Railroad in April 1956, and the other will be delivered to the New Haven Railroad later this year. A major expansion has recently occurred in the number of aluminum tank cars which have been successfully used for some years in transporting hydrogen peroxide, formaldehyde, organic solvents and concentrated nitric acid. A recent demand for concentrated ammonium nitrate solutions for fertilizer use has produced orders for more than 900 such cars within a year.

Domestic Uses of Aluminum

Consumption of aluminum in domestic items has increased greatly. Cooking utensils consumed about 30,000 tons of aluminum last year. Many utensils such as frying pans are being made of cast aluminum with electrical heating elements cast in the bottoms, so they may be connected and used outside the kitchen. Almost 5,000,000 were made last year, with about 4 lb. of aluminum in each. More than 3,500,000 electric coffee makers, averaging perhaps a pound of aluminum apiece, and 4,000,000 electric fans with an average of about 2 lb. of aluminum, were also made.

Because of the warm weather prevailing over most of our country for six to nine months each year, household refrigerators are very widely used, and stores selling meat or fresh vegetables need very large refrigerators. The evaporator units in 80 to 85% of such machines, in which the liquefied gas evaporates and absorbs the heat, are made of aluminum; such parts as trays, shelving and inside doors are also generally made of aluminum – mostly oxide coated and often ornamented in color. More than 4,000,000 refrigerators, each containing an average of 15 lb. of aluminum, were made last year. Home freezers, designed to operate well below the freezing point and averaging 10 cu.ft. in capacity, are coming into general use for freezing and preserving many foods in the home. More than a million of these, containing about 8 lb. of aluminum each, were sold last year.

Household-type vacuum cleaners to the number of 3,300,000 consumed about 5000 tons of aluminum, and electric irons another 4000 tons. Virtually all such "irons" now have aluminum sole plates cast around the heating element. Irons intended to inject steam into the articles being pressed ("steam irons") also have aluminum water tanks and other parts.

A large part of the 100,000 tons of aluminum foil rolled last year found its way into the households of America. About half of it was thin gage, laminated with paper or plastic and used as a vapor barrier and for decorative packages for tobacco, candies, butter and cheese. About 10,000 tons, in gages from 0.0007 to 0.0015 in., were sold as "household foil"; in the home it is chiefly used for wrapping food to be cooked or to be stored in freezers. Disposable containers of aluminum foil, for cakes, pies and other pastry, and for a variety of frozen food products, had a large and increasing market. This growing demand has required large additions to our foil manufacturing capacity.

Electrical industry consumes steadily increasing amounts of aluminum. The present shortage and high price of copper have accentuated this demand, which now totals about 200,000 tons per year. In addition to the general use of "aluminum conductor, steel reinforced" for high-tension transmission lines, insulated power supply and feeder cable has attracted much attention. The latter has been officially approved in all sizes from branch circuits up to 2,000,000 circular mils (about 2 in. diameter), and it is now commercially available covered with all the principal kinds of insulation. Since 1947, all the new factories and office buildings built by Aluminum Co. of America have used aluminum wiring exclusively; more than $200,000 was saved thereby in one large rolling mill. Aluminum busbars are commonly found in secondary distribution systems in factories and office buildings. Western

High Heat Conductivity and Excellent Castability Are Requirements Met in Aircraft Engine Cylinder Heads

Electric Co., the world's largest manufacturer of telephones and telephone equipment, has announced its plans to convert gradually from copper to aluminum, beginning with about 10% of its consumption. The Bell Telephone Co. already has successful experience with a "sample" installation of more than 5000 miles of aerial telephone cable, varying in capacity from 20 to 3000 pairs of aluminum conductors per cable. Switchboard equipment made of light metal is also being tried.

More and more aluminum is going into transformers and motors, wherever space is not a critical requirement. General Electric Co., uses aluminum for the rotor and field coil windings of all the refrigerator motors it makes. The substitution of aluminum for the small brass parts on electric light bulbs and in lamp sockets consumes 8000 tons of sheet a year. Two of the large electric utility companies have installed aluminum-sheathed, high-voltage aerial power cable. In airplanes, aluminum naturally replaces copper in most of the electrical equipment.

Military purposes (including aviation), which required about 90% of the available metal during World War II, now account for only about 10% of the demand. In spite of the merits of magnesium, stainless steel and titanium, aluminum is still the favorite light metal of the aircraft designer and the principal metal used in planes.

Most Modern Equipment Is Available to Produce Sheet and Other Mill Shapes for American Producers

An Over-all View

There are several reasons for the tremendous civilian demand for aluminum that has developed in the United States since the end of the last war. In the first place, the manufacture of aircraft parts during the war, in thousands of large and small plants, taught a whole new group of managers and workers the fabrication and advantages of aluminum. Many of them saw uses for it in their peacetime business when it became available again to civiliaans.

In the second place, a great deal of time and effort had been spent before the war in introducing aluminum, experimentally, in a great variety of plants and processes. Technical laboratory and engineering designs had revealed many of its advantages. Experience was being accumulated before the war, and more was accumulated under conditions of intensive operation during the war. The general success and advantages of these applications were very interesting to the managements involved; consequently the need to repair and reconstruct old plants and equipment after the war, and to build new ones, provided the opportunity to apply this information. Favorable price relationships and shortages in competing materials have naturally also increased the demand for aluminum.

With greatly increased supplies of the metal and plenty of experienced fabricators in all lines, the stage was set for the tremendous and unexpected increased consumption of all forms of the metal. This has resulted in still further increases in productive and fabricating capacity, in an effort (so far unsuccessful) to meet this demand. The industry foresees a continuous and still rapid increase in output, as commercial experience with the metal accumulates in all branches of industry, and more and more manufacturers learn how the metal can be used to their advantage in their processes or products.

Correspondence . . .

More on Aluminum-Silicon Pistons

LEEDS, ENGLAND

We were very interested in the report by J. C. Wagner on the modification of hypereutectic aluminum-silicon alloys by dilute copper in the June issue of *Metal Progress.*

My company carried out considerable investigation some three years ago to determine the best method of reducing silicon particle size and to achieve better distribution. Of the various methods tried, the most consistent was the use of phosphor copper, and since that date all production melts have been so treated.

Phosphor copper is much more effective and much more pleasant to use than phosphorus pentachloride and improves machinability; thus Mr. Wagner confirms the results which we have found in practice in the production of many thousands of complex 22% Al-Si alloy pistons.

E. V. DEWHIRST
Chief Metallurgist
Specialloid Ltd.

LAKE CITY, MINN.

When reading Mr. Wagner's article, "High-Silicon Aluminum Casting Alloy", I was puzzled by the statement that the 22% silicon-aluminum alloy was being used in pistons in Europe while no mention was made of any piston production in this country. The only inference possible is that no pistons are being made from high-silicon alloy here and this is not the true picture.

Vanasil aluminum alloy is a 21 to 23% silicon alloy which has been produced and used in pistons in this country since 1939. During the war it was used extensively in the pistons of small air-cooled engines for the armed services, and we have produced many, many pistons in this alloy for both diesel and smaller engines, since acquiring the Vanasil rights in 1948.

The Vanasil alloy and the high-silicon alloy used in Europe have similar characteristics.

W. C. CHENEY
Vice-President
Gillett & Eaton, Inc.

Metallurgists Wanted Badly

EAST LANSING, MICH.

The colored insert in the July issue of *Metal Progress* will, in my opinion, do much good if the members of follow your advice, cut it out and give it to some bright youngster of high school age. As a matter of fact, the same thing could have been said of your editorial of December 1935, entitled "Trained Metallurgists Needed". The youngsters born that year will this year be graduating from college. We seem to have progressed from "Needed" to "Wanted Badly"!

We must be much more aggressive in going out after the youngsters. As Prof. R. M. Brick wrote two years ago, metallurgy needs "a huckster". Consequently if I were writing the colored insert in the last issue I would have considerably expanded the sections on Opportunities and on Advancement. I would also have enlarged upon your remark on the opportunities for women in the field. While you have indicated there are desirable places open to them, it might have helped to point out that some women have been outstandingly successful.

In a good deal of the written material on this topic the metallurgists seem to be on the defensive – though there is no good reason for it. The metalworking industry including all of its phases is certainly the leading industry not only here but in every industrial nation. Because of our general failure to emphasize on every occasion what the metallurgist is capable of doing we are unable to convince many, even in our own industry, that the metallurgist can more than pay his way. I have in mind an instance of that in the forging industry. I know of a city in the Midwest where there are one captive forge shop and five jobbing shops. Only the captive shop has a metallurgist! The jobbing shops have talked about it but still have no metallurgical control of their operations.

I do not know wherein the fault lies but something is certainly wrong. When these and similar industries put in metallurgical departments it will put a terrific burden on the number of available metallurgists.

In this country we have always risen to the occasion; if anything were needed badly enough we have contrived the means to get it. Thus, one of these days knowledge of the need will trickle through to the high schools. Certainly let us hope that some morning in 1977 we will not open our copy of *Metal Progress* to read "Supply of Metallurgists Desperate"!

A. J. SMITH
Head, Department of
Metallurgical Engineering
Michigan State University

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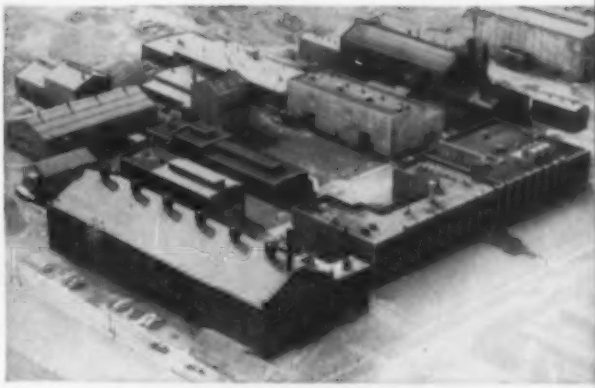
Since 1906 ELECTROMET has carried on a three-way program of research, development, and technical service. More than 300 skilled research scientists, engineers, and technicians work in ELECTROMET's Metals Research Laboratories and Development Laboratories at Niagara Falls (shown here). This program provides you with new ferro-alloys and metals, better ways of using them, and new and improved alloy steels and irons. Innovations are fully developed in our laboratories before they are offered commercially.



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Personal Mention

Stanislaus Skowronski

Kempton H. Roll

STANISLAUS SKOWRONSKI, research engineer at the Raritan Copper Works of the International Smelting & Refining Co., Perth Amboy, N. J., a subsidiary of the Anaconda Co., retired recently on the eve of his 75th birthday.

Born in Switzerland, Mr. Skowronski received his technical education at Massachusetts Institute of Technology, graduating in 1904. Two years later he joined the American Smelting and Refining Co. in Perth Amboy, as a chemist, but left in 1912 to join the International Smelting & Refining Co.'s Raritan Copper Works. At his retirement, Mr. Skowronski had been associated with the company for 44 years.

Mr. Skowronski has written many articles on copper, including the chapter on copper in the new Encylopedia Americana. He also has lectured extensively and served as an adjunct professor at the Polytechnic Institute of Brooklyn for 25 years.

A member of numerous technical societies, Mr. Skowronski was active on the early B committees of the American Society for Testing Materials and has served as his company's representative to that society for 30 years. He is also founder of the Technical Societies Council of New Jersey, serving as president in 1944 for one year, and is a past chairman of the New York Chapter.

The Metal Powder Association, New York, has appointed KEMPTON H. ROLL as the first full-time executive secretary and treasurer of the organization.

Mr. Roll received his metallurgical education at Carnegie Institute of Technology and Yale University, graduating from Yale in the fall of 1944. After two years' service in the Navy, he joined the Magnolia Metal Co., Elizabeth, N. J., as a research and production metallurgist, but left the company in 1948 to join the Lead Industries Assoc. and Metal Powder Assoc. as staff metallurgist. At the time of his new appointment, Mr. Roll was technical director of both the Metal Powder Assoc. and Lead Industries Assoc. During this period, he continued his studies and in 1953 received a master's degree from the Polytechnic Institute of Brooklyn.

Mr. Roll has written numerous technical papers on lead and its alloys and on powder metallurgy. He is also active in many technical organizations; currently he is chairman of both the New York Chapter and the New York powder metallurgy group of the American Institute of Mining, Metallurgical and Petroleum Engineers. He served as general conference chairman of the 1956 International Corrosion Conference sponsored by the National Assoc. of Corrosion Engineers.

Paul C. Mortenson has joined Vickers, Inc., Detroit, as chief engineer, ground mobile products. Mr. Mortenson was administrative engineer, western hemisphere, for Massey-Harris-Ferguson, Inc., Racine, Wis., before coming to Vickers.

Robert C. Wayne has been appointed to the newly created post of advertising and public relations manager, Southwestern Engineering Co., Los Angeles. Prior to his present position, Mr. Wayne had been associated with the Surface Combustion Corp., Toledo, Ohio, for eight years as advertising manager for the company's industrial divisions.

Robert B. Winder is now a sales engineer in the Detroit office of the steel and tube division, Timken Roller Bearing Co., Canton, Ohio. A graduate of Wayne University, Mr. Winder recently completed a course of sales training in Timken's steel and tube division.

A. H. Davis has retired from his position of works manager at the R. K. LeBlond Machine Tool Co., Cincinnati. Mr. Davis joined the firm in 1935 as assistant works manager and was named works manager in 1953.

John B. Giacobbe, formerly plant metallurgist at the Superior Tube Co., Norristown, Pa., has been assigned to direct the nuclear products division of Superior Tube. This new division will be located in Trappe and Phoenixville, Pa.

A. R. Attebury has retired as district manager of the New York steel and tube division of Timken Roller Bearing Co., Canton, Ohio. Mr. Attebury, who has been associated with Timken for 22 years, will be retained by the company as a sales consultant.

G. B. Wadsworth is now a metallurgist with Combustion Engineering, Inc., Chattanooga, Tenn. A 1954 graduate of Birmingham-Southern College, Mr. Wadsworth previously worked as a research assistant in physical metallurgy at Oak Ridge National Laboratory.

Robert N. Lynch ●, formerly sales manager of Park Chemical Co., Detroit, has been appointed sales manager of the Industrial Heating Equipment Co., Detroit.

John L. Miller ● has assumed new duties as director of defense activities for the Firestone Tire & Rubber Co., Akron, Ohio. Dr. Miller joined Firestone in 1941, serving successively as chief metallurgist, assistant production manager of Firestone Steel Products Co., and finally as manager of the defense research division after its organization in 1950.

Bradley B. Evans ● was elected president of the Alloy Casting Institute at the Institute's annual meeting in Hot Springs, Va., last summer. Mr. Evans is sales manager of Empire Steel Castings Inc., Reading, Pa. At this same meeting, **E. A. Schoefer** ● was re-elected executive vice-president and treasurer of the Institute.

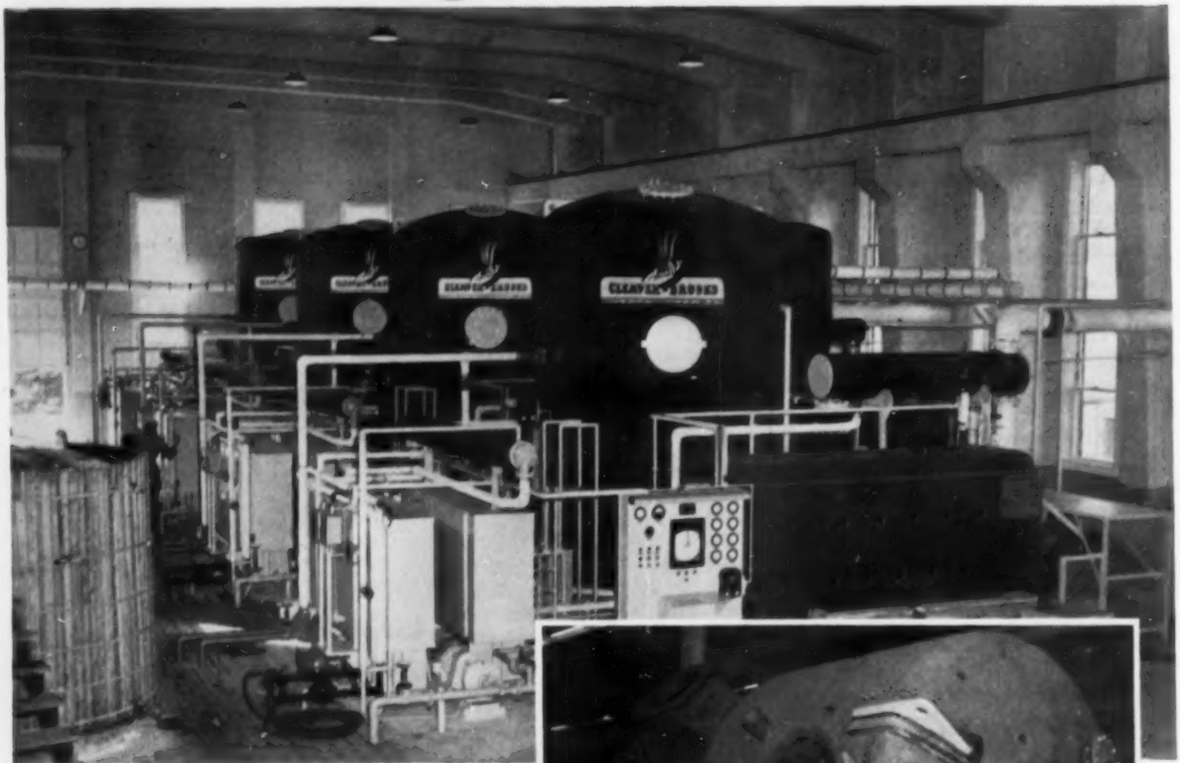
Henry J. Wesolowski ● is now working in the materials and methods engineering department of the electronic systems division at Sylvania Electric Products, Inc., Waltham, Mass.

Garrett B. LeVan ● has been appointed manager of rod and bar operations for Mallory-Sharon Titanium Corp., Niles, Ohio. Prior to his recent appointment, Mr. LeVan was general manager of the Titusville, Pa., plant of Universal-Cyclops Steel Corp.

William Wilson ● has been named to the newly created post of director of research and development at A. Finkl & Sons Co., Chicago. Mr. Wilson was formerly supervisor of metallurgy at Ekco Products Co., Chicago, and a research metallurgist at the Armour Research Foundation of Illinois Institute of Technology.

Robert J. MacDonald ●, formerly principal metallurgist at Battelle Memorial Institute, Columbus, Ohio, is now senior metallurgist with the Clevite Research Center, Cleveland.

Craig O. Malin ● is now a research engineer at the Rocketdyne Div., North American Aviation, Inc., Canoga Park, Calif.



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Made and installed by CLEAVER-BROOKS

... Vital distillation units fabricated from REVERE SILICON BRONZE

This plant installed at the Kindley Air Force Base in Bermuda has a total daily capacity of 200,000 gallons and eliminates the dependence of the Base on rainfall or shipment of water by tankers.

Distilled water is produced in the ratio of 300 lbs. to each pound of Diesel fuel. Total costs are estimated at $1.25 per thousand gallons of distilled water. Nearly every component part made by Cleaver-Brooks is about twice the size of its largest previous counterpart. For example, the evaporators are 16½ feet high. Each, with its component parts, weighs approximately 40,000 lbs., the empty Revere Silicon Bronze shell alone accounting for 28,000 lbs.

There is an interesting story behind the development and manufacture of this equipment. The four huge pressure vessels had to be fabricated of Revere Silicon Bronze Alloy No. 420. Knowing Revere's wide experience in welding copper-base alloys, Cleaver-Brooks called in a Technical Advisor, and gave him a complete set of blueprints of the vessels, with a request for suggestions regarding joint design and welding techniques. He in turn consulted the Welding Section of the Revere Research Department. Their recommendations were adopted, and the customer reported that the original estimate of welding time had been cut considerably, reducing production costs correspondingly.

The Revere Technical Advisory Service is glad to collaborate on problems involving the specification and fabrication of copper and copper-base alloys, and aluminum alloys. See the nearest Revere Sales Office.

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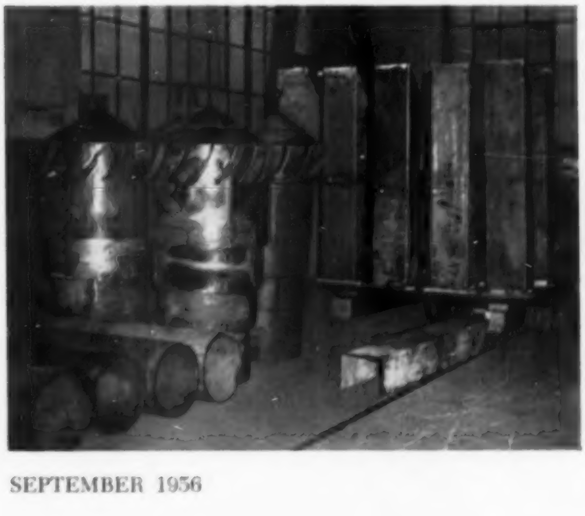

THE STEAM SEPARATORS are identified by their conical tops and directional vanes. They are of the cyclone type, which is a patented feature of CLEAVER-BROOKS evaporators, and remove entrained water from the steam, thus preventing contamination of the fresh water coming from this unit. The result is an extremely high purity of the fresh water product.

The rectangular objects at rear of photograph are the "Downcomers" which bring water down from the top of the steam separator. The tubes in left foreground are "Hotwells," which receive the distilled water discharge from the evaporator shell.

Personals . . .

Henry R. Clauser has assumed the post of editor of *Materials & Methods*, New York. Formerly managing editor, Mr. Clauser has been with *Materials & Methods* for more than 11 years. He came to the staff in 1941 and after a short time left to join the U. S. Army. Returning in 1946, he served as associate editor until his appointment as managing editor in 1950.

John H. Shue, Jr., was promoted to metallurgist technician, working with the staff heat treat engineer, at Caterpillar Tractor Co., York, Pa.

Walton S. Smith has retired as vice-president in charge of manufacturing of Metal & Thermit Corp., New York, after 37 years with the company. Joining Metal & Thermit in 1919 as a mechanical engineer, Mr. Smith became assistant superintendent of the Carteret, N. J., plant in 1925 and superintendent in 1937. He was elected vice-president in 1942 and a year later became a director of the company. Mr. Smith will continue as a director and also as a consultant for the company.

Rudolph A. Schatzel has been elected president of the American Society for Testing Materials for a one-year term. Mr. Schatzel is vice-president and director of engineering, Rome Cable Corp., Rome, N. Y., a post he has held since 1945. **Howard C. Cross** has been elected a director of the American Society for Testing Materials. Mr. Cross is assistant technical coordination director, Battelle Memorial Institute, Columbus, Ohio, and has been with Battelle since 1929.

T. F. McCormick, formerly staff metallurgist at the Pittsburgh office of the Aluminum Co. of America, has been promoted to the post of assistant chief metallurgist. **W. E. King**, another staff metallurgist in the Pittsburgh office, has been named chief development metallurgist, and **K. B. Baker**, formerly chief metallurgist at the Edgewater, N. J., Works, is chief control metallurgist in Pittsburgh.

Non-Habit-Forming

Pressure gage courtesy J. E. Lonergan Co., Philadelphia 6, Pa.

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Personals . . .

Clemens C. Sutinen ⊕ has joined the staff of the Mannesmann-Meer Engineering and Construction Co., Easton, Pa., as technical sales engineer with the powder metallurgy equipment division, representing the interests of Simetag GmbH., Moenchen-Gladvach, Germany, powder metallurgical subsidiary of Mannesmann-Meer. Mr. Sutinen formerly was associated with Welded Carbide Tool Co., Inc.

L. F. Bledsoe, Jr. ⊕ was recently promoted from project engineer in the atomic power design division of the Newport News Shipbuilding & Dry Dock Co., Newport News, Va., to technical assistant to the manager of the atomic power installation division of the company.

H. A. Anderson ⊕ has been added to the staff of the industrial furnace division of the Gas Machinery Co., Cleveland, in the capacity of staff engineer. Mr. Anderson was formerly employed by Lindberg Industrial Corp., Chicago.

Herbert A. Jahnle ⊕ has been released from the U. S. Army Chemical Corps, Dugway Proving Ground, Dugway, Utah, and is now a metallurgical engineer with the Budd Co., Philadelphia.

William J. Stewart ⊕ has been transferred from the Washington district sales office of Youngstown Sheet & Tube Co. to the Cincinnati district sales office.

John R. Rink ⊕, recently released from active duty in the U. S. Army, is presently employed as technical service metallurgical engineer with Inland Steel Co., East Chicago, Ind. While in the Army, Mr. Rink served as a metallurgical engineer in the ballistics research laboratory at Aberdeen Proving Ground, Aberdeen, Md.

N. A. Wagner ⊕ has been transferred from the Reynolds Metals Co. extrusion plant in Grand Rapids, Mich., to the new Reynolds extrusion mill in Richmond, Va. He will be manager of the metallurgical department in the new plant.

Personals . . .

Joseph J. White ⊕ has been named director of research and metallurgy at Erie Forge & Steel Corp., Erie, Pa. Mr. White will be assisted by **George E. Danner** ⊕, newly appointed assistant director of research and metallurgy.

Joseph J. Tompos ⊕, a recent recipient of a master's degree in metallurgy from Ohio State University, has returned to the U. S. Steel Corp. as supervising technologist, high strength steels, at the applied research laboratory in Monroeville, Pa.

Arnold S. Grot ⊕ has been named chief metallurgist for Edward Valves, Inc., East Chicago, Ind., a subsidiary of Rockwell Mfg. Co. Before coming to Edward Valves ten years ago. Mr. Grot was chief metallurgist for Taylor Forge and Pipe Works, Cicero, Ill.

Burns George ⊕, vice-president of sales, Vanadium-Alloys Steel Corp., Latrobe, Pa., has been elected a director of the Washington Steel Corp., Washington, Pa. Mr. George has been with Vanadium-Alloys Steel since 1923 and is also a director of that company and Vanadium-Alloys Steel Ltd., London, Ont.

Yeshwant P. Telang ⊕ recently was promoted from supervisor, quality analysis section, specialty foundry, Ford Motor Co., Dearborn, Mich., to research metallurgist, research and development department.

Samuel Storchheim ⊕ is now assistant chief, materials section of the Glenn L. Martin Co., Baltimore. Mr. Storchheim was formerly associated with the atomic energy division of Sylvania Electric Products Corp., Bayside, N. Y.

Lloyd R. Cooper ⊕ has been promoted to chief metallurgical engineer of the Heppenstall Co., Pittsburgh. Joining Heppenstall in 1942 as a research metallurgist, Mr. Cooper has served as director of research, chief metallurgist of the Eddystone, Pa., plant and more recently as assistant chief metallurgical engineer of the company.

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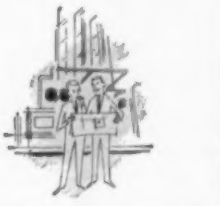

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Personals . . .

Marvin J. Udy ⊕ has received an honorary Doctor of Science degree from Alfred University in recognition of his achievements in the field of electric furnace research. Dr. Udy is an associate and consultant of Stratmat, Ltd., and is connected with Strategic-Udy Metallurgical & Chemical Processes, Ltd.

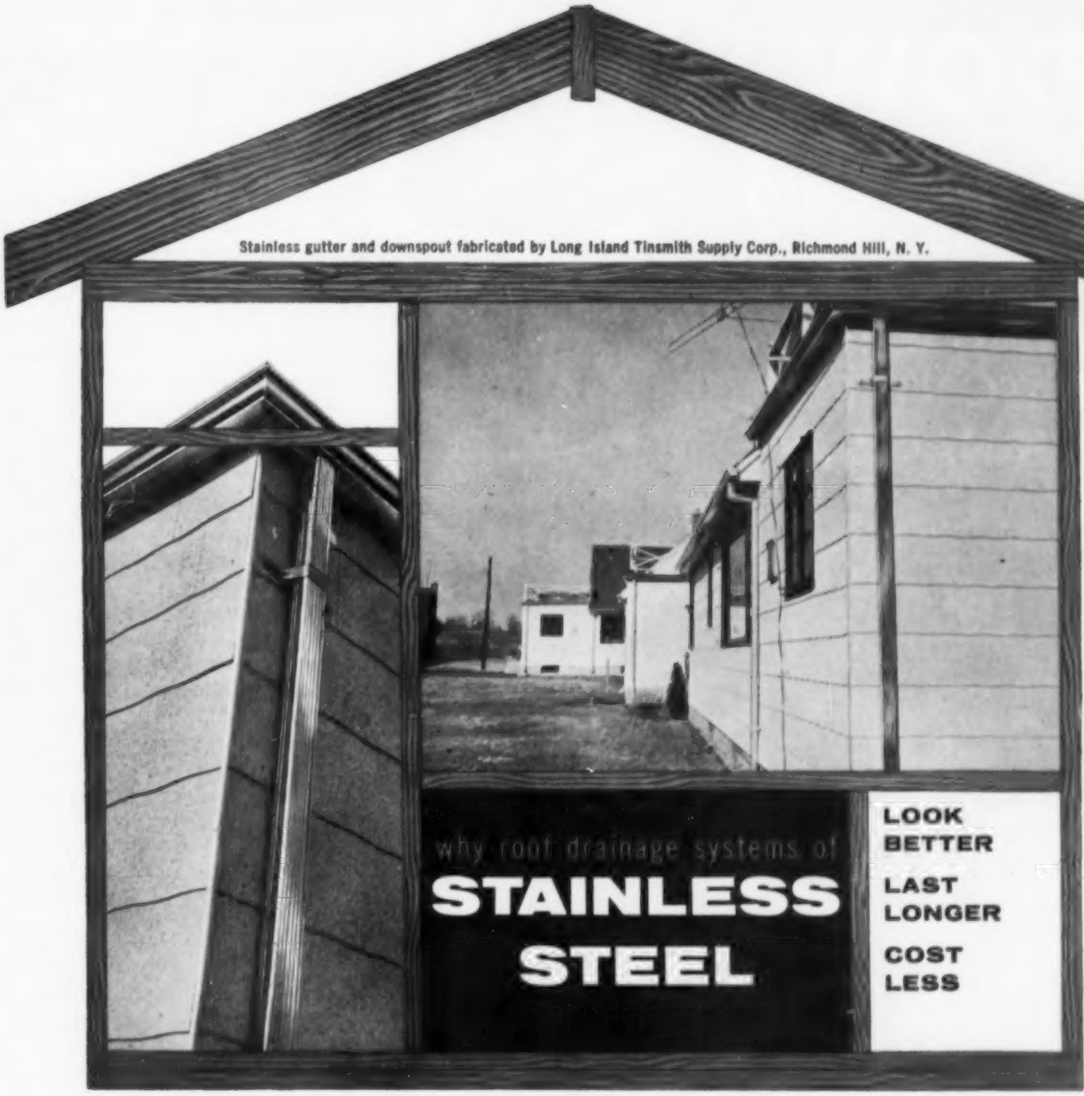
Maurice F. Garwood ⊕ was awarded the professional degree of metallurgical engineer at the Ohio State University commencement exercises in June in recognition of his engineering ability and accomplishments in the field. A 1933 graduate of Ohio State, Mr. Garwood is chief materials engineer for the Chrysler Corp., Detroit. He joined Chrysler in 1941.

Richard A. Wilkins ⊕, vice-president in charge of the research and development department of Revere Copper and Brass Inc., Rome, N. Y., has been elected a Fellow of the Institute of Metals in London, England. The number of Fellows is limited to 12, and Mr. Wilkins is the first nonresident of the United Kingdom to receive this honor.

Paul Ffield ⊕ has been named an assistant manager of research at Bethlehem Steel Co., Bethlehem, Pa. Mr. Ffield is one of two assistant managers who succeed **John S. Marsh** ⊕, recently promoted to manager of research.

Eraldus P. Scala ⊕ has become head of the materials section, research and advanced development division, Avco Mfg. Co., Stratford, Conn. For the past eight years, Dr. Scala has been associated with the Chase Brass & Copper Co., Waterbury, Conn., as metallurgist, training director and, since 1953, head of the physical metallurgy group in the research department.

Macon Jordan ⊕ has been named product manager, toolsteel sales, in the Cincinnati plant area for Solar Steel Corp., Cleveland. Mr. Jordan was formerly associated with Universal-Cyclops Steel Corp. and Firth Sterling, Inc., where he served as Ohio district sales manager.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Personals . . .

Four members of the American Society for Metals received Awards of Merit at the annual meeting of the American Society for Testing Materials held in Atlantic City last summer. **W. L. Fink**, chief of the physical metallurgy department at the Aluminum Research Laboratories, Aluminum Co. of America, New Kensington, Pa., was honored for his contribution to the fields of metallography and X-ray diffraction. **Bruce W. Gonser**, assistant director of Battelle Memorial Institute, Columbus, Ohio, and **Roland P. Koehring,** section engineer for research and development, Moraine Products Div., General Motors Corp., Dayton, Ohio, received awards in recognition of their leadership and support in standardization and research work, Mr. Gonser in the field of nonferrous metals and alloys and Mr. Koehring in powder metallurgy. **Vincent T. Malcolm**, consultant and advisory engineer, Chapman Valve Mfg. Co., Indian Orchard, Mass., was recognized for his long-time support of many standardization and research projects and for his work on the effects of temperature on metals.

H. M. Clarke is now vice-president of Detroit operations and general manager of the Detroit plant of Bliss & Laughlin, Inc., Harvey, Ill.

John Wallerius has been appointed chief engineer of the Lindberg Industrial Corp., Chicago. Before joining Lindberg, Mr. Wallerius was associated for 25 years with the furnace division of Sunbeam Corp., Chicago, as chief engineer, and more recently with Sigma Metallurgical Co. as president.

John B. Seastone has been appointed director of the technical division, Olin Mathieson Chemical Corp., East Alton, Ill. Mr. Seastone was formerly research and development manager for the metals division of the company. Before joining Olin Mathieson, he was manager of the materials division for Westinghouse Electric Corp., and a recipient of the Westinghouse Award of Merit.

Personals . . .

E. A. Nave ⊕ has been appointed sales manager, fabricated products, metals division, Olin Mathieson Chemical Corp., East Alton, Ill. Mr. Nave was production manager of the brass strip operation and technical advisor to the vice-president of operations for the company before his new appointment.

D. K. Crampton ⊕, director of research and development, Chase Brass & Copper Co., Inc., Waterbury, Conn., presented the fifth Gillett Memorial Lecture on "Structural Chemistry and Metallurgy of Copper" at the annual meeting of the American Society for Testing Materials last summer. This lecture, sponsored jointly by the A.S.T.M. and Battelle Memorial Institute, Columbus, Ohio, commemorates H. W. Gillett, first director of Battelle, and each year covers a subject pertaining to the development, testing, evaluation and application of metals.

G. D. Smelzer ⊕ has been promoted to district manager of the Hamilton, Ont., branch of the Railway & Power Engineering Corp.

John A. Hincks ⊕ has joined the metallurgical staff of Battelle Memorial Institute as a project engineer in the metals joining division.

J. E. Williams ⊕, formerly vice-president for operations, metals division, Olin Mathieson Chemical Corp., East Alton, Ill., has been appointed vice-president and general manager of the Western Brass Mills Div. Mr. Williams will direct operations at East Alton and also the company's brass mills at New Haven.

A. E. White ⊕, consulting engineer, retired director of the Engineering Research Institute and professor of metallurgical engineering at the University of Michigan, Ann Arbor, was presented an honorary membership in the American Society for Testing Materials at the society's annual meeting last summer. Dr. White has been a member of A.S.T.M. since 1914, and was the first national president of the American Society for Metals in 1920.

Digests of ASM Convention Papers

Fatigue Life of Aircraft Quality Versus Vacuum Melted 4340

Digest of "Relation of Inclusions to the Fatigue Properties of S.A.E. 4340 Steel", by H. N. Cummings, F. B. Stulen and W. C. Schulte. ASM Preprint No. 23, 1956.

THE FATIGUE strength of many alloy steels is related to the quantity of nonmetallic inclusions. In this paper the fatigue strengths of approximately 1000 smooth R. R. Moore specimens of a single commercial S.A.E. 4340 steel of aircraft quality and about 100 specimens of a single high-purity heat vacuum melted are compared. S-N curves were obtained for both smooth and notched specimens at nominal ultimate tensile strengths at three levels (140,000, 190,000 and 260,000 psi.). From data and a microscopic examination of the surface of the specimens, the location of the fractures, the nature of the fractured surface and the inclusion content were related to the fatigue strength. At the lower stress level most of the failures originated at small inclusions open to the surface, Their size was measured and, since most of them were spheriodal, the "geometric mean diameter" of the exposed cross section was adopted as a size parameter. It was found by statistical analysis that there was a relation between the sizes of the inclusions associated with failures and the life of the specimens. (For specimens where the fractures occurred at a considerable distance from the minimum cross section, the actual fatigue life was adjusted to what it probably would have been if the central inclusions had been at the minimum cross section.)

At higher stress level (190,000 and 260,000 psi.), the relatively simple correlation between size of inclusions and fatigue life was altered. Multiple nuclei of fracture appeared in increasing numbers of specimens. In some, a rather large inclusion appeared in a nucleus at a measurable distance below the surface of the specimens of relatively long life.

Nuclei could be measured and counted (but no inclusions) in the vacuum melted steels tested on the 190,000-psi. strength level, and the *number* of nuclei increased faster than in the commercial steel. The figure shows that the endurance limit (50% probability) for the two varieties is about the same at 140,000-psi. strength level, even though the vacuum melted steel has twice the number of fracture nuclei (8 versus 4). The authors suggest that the vacuum melted steel may have submicroscopic inclusions or stress raisers of a physical nature.

The authors make the following "predictions":

1. The first microcrack appearing on the surface of the specimen will always be associated with a large inclusion, regardless of the stress level, but the final fracture may not be associated with the first crack.

2. The variance of the location of the *first* microcrack will be independent of the stress level.

3. As is also true of fatigue at high stress levels, the static tensile fracture will be initiated at the location having the largest number of small inclusions in or about one plane.

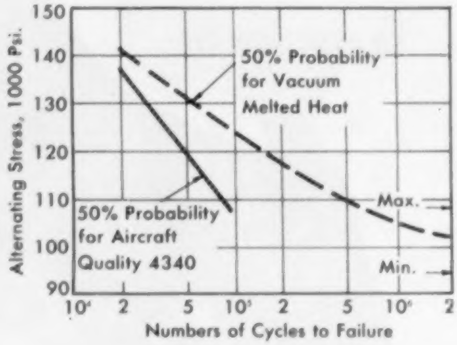
4. The number of cracks appearing on the surface of a "failed" fatigue specimen away from the fractured surface increases with the stress level. (This could account for the sagging of specimens under high stress.)

5. Material such as vacuum melted steel having numerous, extremely small, inclusions or discontinuities will have a flatter slope of the upper branch of the S-N curve when compared to that of a commercial heat.

6. If all the very small inclusions and other microstress raisers could be eliminated from metal, its fatigue life under very high overstresses would be increased by a large amount.

7. Similarly, if only the *large* inclusions were eliminated (which occurs in steels vacuum melted from pure raw materials), the life for low fatigue overstress would be greatly increased even though fatigue life for high overstress would be improved little if at all.

D. J. CARNEY



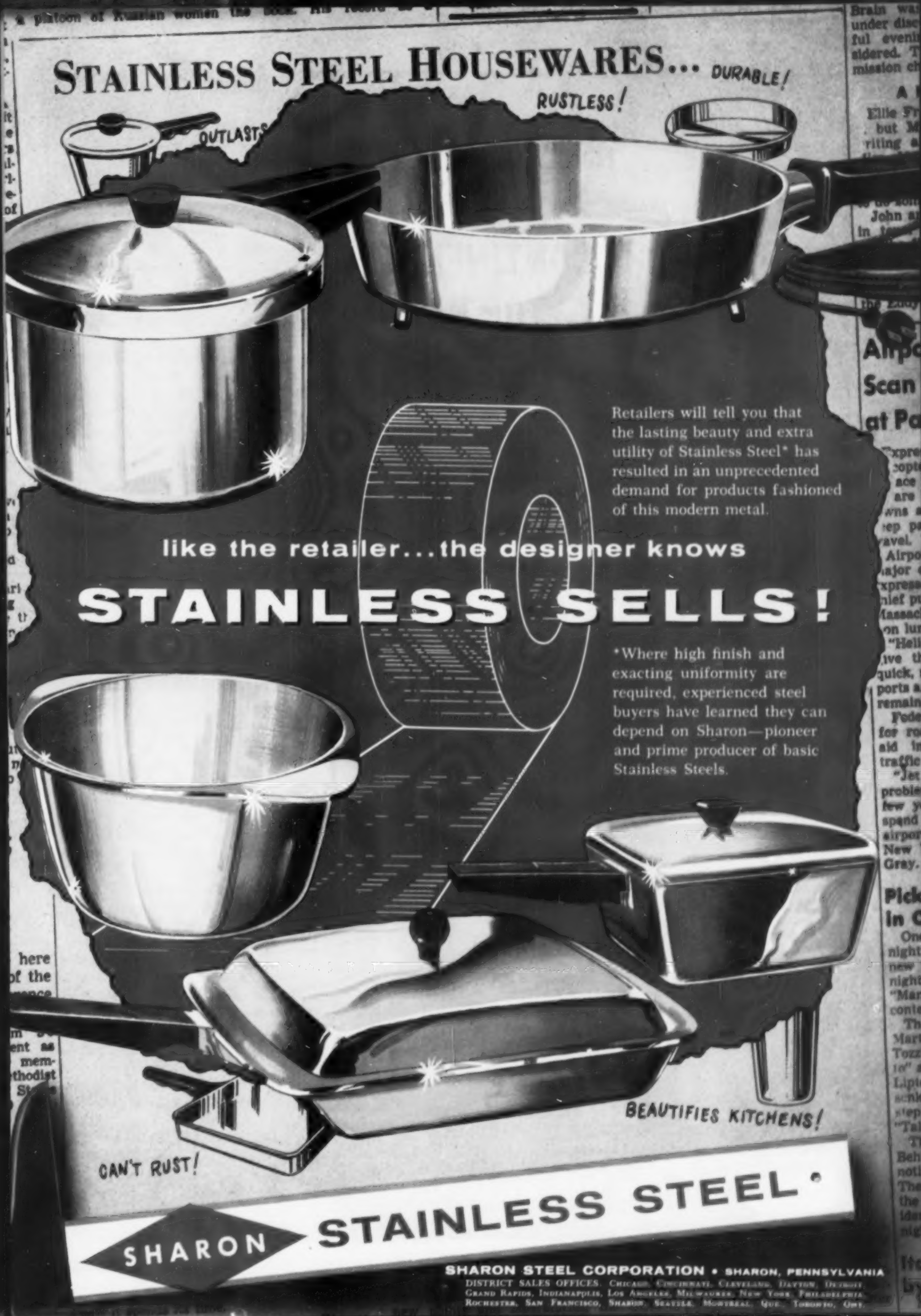
S-N curves of S.A.E. 4340, Aircraft Quality Vs. Vacuum Melted, Heat Treated to 190,000-Psi. Tensile and Tested as Rotating Beam

Temperability of Steels

Digest of "Temperability of Steels", by L. D. Jaffe and Edward Gordon. ASM Preprint No. 14, 1956.

A NEW METHOD of calculating the proper tempering temperature for a quenched steel to obtain a specific hardness is described in this paper. It is a much simpler and more rapid system than others which have been used and is reported to be more accurate.

Six charts are used in conjunction with a simple equation to make the necessary calculations. The first three charts are used to read off the contribution of alloying elements and grain size to "composition hardness".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Temperability . . .

This figure is introduced into the simple equation to allow a first approximation of the tempering temperature and the three succeeding charts are used to refine the first approximation.

The computations are based on statistical analysis of about 5000 hardness measurements of samples from 85 heats of steel. The authors indicate that the empirical relationship developed should be used cautiously for steels whose compositions are much outside the range of alloys studied. Another limitation is the requirement that the structure of the steel before tempering should consist essentially of martensite.

The standard deviation of this method, where applied to the experimental data, is 39° F., which is equivalent to Rockwell C-1.3. The results are slightly more accurate than can be obtained by the methods developed by Crafts and Lamont or Grange and Baughman. The calculations are much simpler and less time-consuming.

W. A. REICH

New Nodular Iron Process

Digest of "New Nodular Iron Process", by Harry K. Ihrig. Preprint No. 7, 1956.

MANY ATTEMPTS have been made to modify the graphitic structure of cast irons, and mechanical properties are improved when the graphite is in spheroidal particles rather than in flakes. Cerium and a nickel-magnesium alloy have both been successful additives for producing this "spheroidal" or "nodular" graphite. Sodium is also effective. The magnesium process is most widely used today in the United States. Cerium or misch-metal additives are considerably more expensive.

Magnesium is added to molten iron with difficulty because of its high vapor pressure and its explosive reaction with oxygen at molten iron temperatures. The use of dilute alloys with nickel or copper reduces the hazard but is an added cost, and the diluting elements tend to concentrate in the scrap.

This paper describes the use of chlorides (and the other halides) of sodium, magnesium, strontium, lith-

Grand Rapids, Indianapolis, Los Angeles, Milwaukee, New York, Philadelphia, Rochester, San Francisco, Sharon, Seattle, Montreal, Que., Toronto, Ont.

IT'S BETTER IF IT CONTAINS MOLY

Nodular Iron . . .

ium, rubidium, barium and cerium when combined with calcium silicide (30% calcium) as a reducing agent.

The molten base iron (total carbon 3.81% to 4.34%, silicon 0.63 to 0.68%, phosphorus 0.025 to 0.060%, sulphur 0.023 to 0.039% and manganese 0.10 to 0.15%) was poured into a ladle containing various mixtures of calcium silicide and the above-mentioned halides. After completion of the reaction, the slag is skimmed and the iron cast into molds.

The mechanical properties of the heat poured on magnesium chloride showed the best properties, with a yield point of 47,500 psi., tensile strength of 80,500 psi., and elongation of 13%. The cast with sodium chloride also showed good tensile strength but elongation was 3%.

Because these two were most successful in the experimental heats, a number of commercial heats were made using mixtures of sodium and magnesium chlorides and calcium silicide. Two typical heats are described which had the following additions: 0.4% sodium chloride, 0.8% magnesium chloride and 1.8% calcium silicide. These heats as well as other commercial heats were melted in a basic lined cupola – although other methods which produce low-sulphur irons may also be used.

Chemical anlysis of these heats showed that the nodulizing action reduced the total carbon about 80 points, and the sulphur to very low figures (0.01 or less). Manganese and phosphorus were unchanged at 0.50 and 0.050 respectively. Silicon was more than doubled (to 2.90%) and a small amount of magnesium (0.025%) is retained.

Mechanical properties after nodulizing are as follows: tensile strength 79,500 and 84,400 psi., yield 60,000 and 64,000 psi., elongation in 2 in. 19.5 and 12.5% and Brinell hardness 187 and 197, respectively.

Microstructures of the above irons were a mixture of ferrite, pearlite and nodular or spheroidal graphite.

Approximately 1400 tons of various castings were cast using the above campaign with so much success that a 54-in. basic-lined cupola with a melting rate of 10 tons per hr. has been put into service by Allis-Chalmers Mfg. Co.

PAUL G. NELSON

Toughness of Malleable at Low Temperature

Digest of "Notch Ductility of Malleable Irons", by G. A. Sandoz, N. C. Howells, H. F. Bishop and W. S. Pellini. Preprint No. 6, 1956.

THIS STUDY is on malleable iron specimens containing sharp notches. The temperature at which failure occurs without prior plastic deformation ("nil ductility transition") was determined by a drop-weight test. The notch is a cleavage crack produced by laying down some brittle weld material on the surface of the specimens. Explosion tests and Charpy V-notch tests were also made to determine if the same correlations exist in malleable irons as previously observed for other ferrous materials. The effects of chemical composition, microstructure and section size were determined for experimental malleable irons, and the results compared with commercial malleable irons, nodular irons and other ferrous materials.

Phosphorus in the range 0.03 to 0.20% increases the nil ductility transition from −150 to 0° F. while sulphur (0.024 to 0.200%) has little if any effect, especially below −150° F. provided more manganese is present than the amount needed to combine with the sulphur. An increase in section size increases the nil ductility transition in untreated irons, but inoculants which insure a nodular type of graphite eliminate the size effect. Commercial ferritic irons of this kind have a nil ductility transition at about −50° F. in section sizes up to 3 in.

Pearlitic malleable irons appear to be sensitive to the type of heat treatment. Heat treatments to Brinell hardnesses between 160 to 190 have nil ductility transition between 10 and 70° F. Removing any decarburized surface generally raises the transition temperature about 20° F.

When the nil ductility transition temperature is correlated with curves showing the Charpy V-notch energy transition, it appears that brittle fracture without prior plastic deformation occurs. The explosion crack-starter tests show that brittle fractures may be forced to occur at temperatures above the nil ductility transition only when severe deformation occurs. At temperatures approx-

Malleable Iron . . .

imately 50° F. above the nil ductility transition temperature, the propagation of brittle fracture becomes so difficult that the sample does not completely fracture.

When compared with other ferrous materials, it is observed that ferritic malleable irons have similar notch ductility values to low-silicon, low-phosphorus, ferritic nodular irons. Pearlitic malleable irons properly inoculated compare favorably with average ferritic nodular irons, rolled semikilled, and fully killed mild steel plate.

G. J. Salvaggio

Air Contamination of Titanium Alloys

Digest of "A Study of the Air Contamination of Three Titanium Alloys", by J. E. Reynolds, H. R. Ogden and R. I. Jaffee. ⊕ Preprint No. 11, 1956.

The upper temperature limits for forging and rolling titanium alloys have been restricted because of the inward diffusion of oxygen and nitrogen when billets are heated in air. The hot working range has usually been determined by trial and error and this study was designed to develop a more precise method of predicting safe temperature limits.

Cylindrical specimens were heated in a static air atmosphere of an electric muffle furnace for various periods of time up to 24 hr. at temperatures up to 2100° F. To determine the uncontaminated base-hardness levels, control specimens were heated in argon at each temperature. Four microhardness traverses from the surface extending inward were made on each specimen to obtain a hardness penetration curve.

Diffusion coefficients associated with the contamination process were calculated by applying the Van Ostrand-Dewey diffusion analysis to hardness penetration curves. Parametric equations were derived which express the depth of contamination as a function of time, temperature and the activation energy associated with the contamination process. Nomographs summarizing the findings are presented for three alloys.

G. A. Fritzlen

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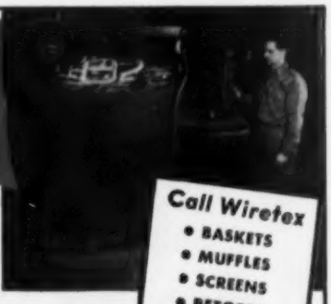

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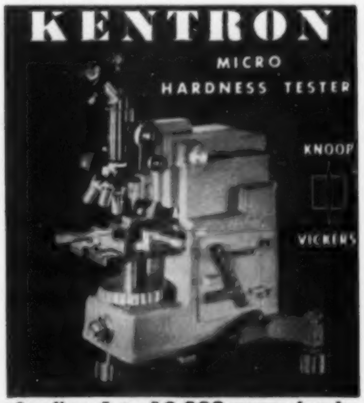

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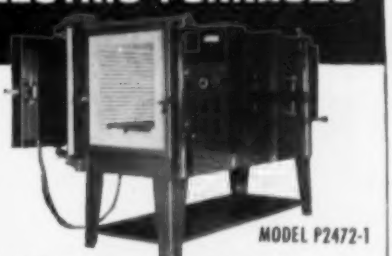

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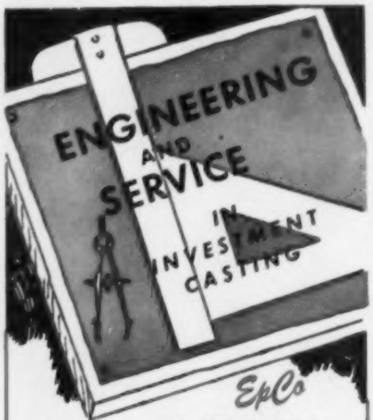

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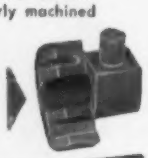

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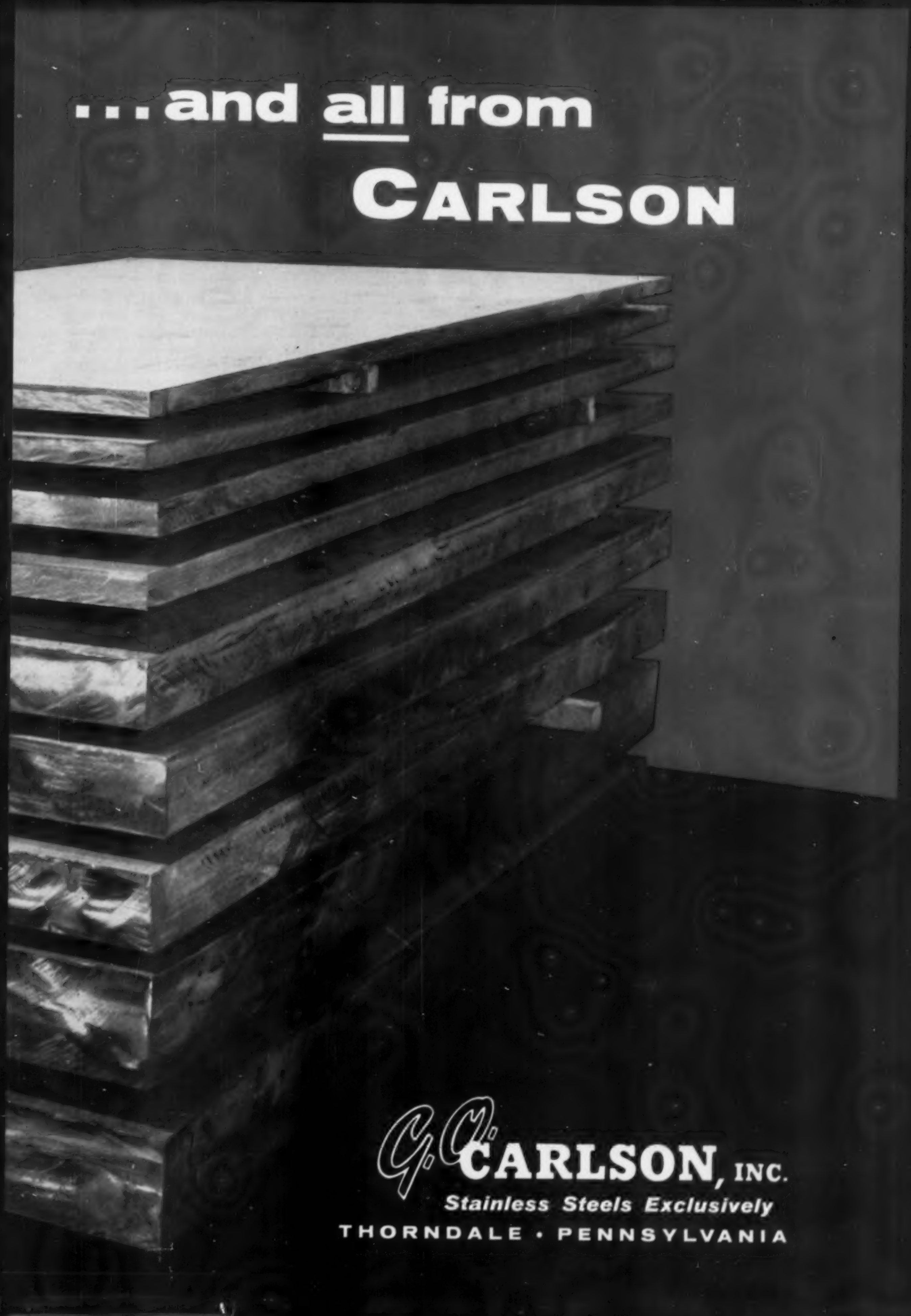
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Transformation on Continuous Cooling

Digest of "On the Cooling Transformations in Some 0.40% Carbon Constructional Alloy Steels", by D. J. Blickwede and R. C. Hess. ⊕ Preprint No. 17, 1956.

In steel practice, most hardening is done by quenching as rapidly as possible from the austenitizing temperature. Isothermal treatments – so-called – quench only part way down to room temperature, and a vast amount of work has been done on the microstructure and properties of steels so treated. However, few have followed the lead set in 1944 by Liedholm and Blickwede in studying the transformation of aircraft and propeller steels during continuous cooling at rates possible in various commercial quenching solutions and dies – which as remarked above, is the ordinary method of heat treatment. To construct such a cooling transformation diagram (or C.T. diagram), a series of bars may be end-quenched for various periods of time and then quenched in brine, which "freezes in" the structures existing along the bar at the time of quench. Metallographic and hardness surveys then give the data from which C.T. diagrams are constructed.

In this paper C.T. diagrams were determined on A.I.S.I. 4340, 9840, 86 B 40, 4140 and 5140. Except for the 4140 (which was a 4-in. round), all steels were 1¼ to 1½-in rounds. Liedholm's method was expanded to include the measurement of transformation by lineal analysis and determination of M_s temperatures. The diagrams therefore show the *amounts* of transformation at any time – information not usually contained in previously published diagrams.

The following pertinent observations can be made:

1. If the criterion is the *beginning* of transformation, hardenability is controlled by the bainite reaction. However, if the criterion is 99% transformation (99% martensite), the bainite reaction controls hardenability of 4340 and 9840 whereas pro-eutectoid ferrite controls hardenability of 86 B 40, 4140 and 5140.

2. If the criterion is 50% transformation, the formation of bainite and pro-eutectoid ferrite controls hardenability of 86 B 40 and 4140, but


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the pearlite reaction combines with them for 5140.

3. The portion of the end-quenched bar which was below the M_s temperature before the final quench in brine contains a tempered, dark-etching martensite whereas the portion which was above M_s contains untempered, light-etching martensite. This led to a method for determining M_s, and the values checked within 15 to 35° F. of calculated values (except on the 4140 specimen which had not been completely austenitized). Hardness values at the ¼-in. position on the 4340 steel decreased as much as three points on the Rockwell C scale because of the simultaneous formation and tempering of martensite.

4. The M_s temperatures of all five steels examined were lowered by slow cooling. The magnitude of this effect was not related to prior bainite formation. With 4340 and 9840 it seemed to depend only on the cooling rate. With 4140 and 5140 it appeared to result from carbon enrichment of untransformed austenite during the preceding formation of pro-eutectoid ferrite. The presence of retained austenite in slow-cooled 4140 was confirmed when the hardness increased three to five points on the Rockwell C scale after refrigerating to −321° F. Because less pro-eutectoid ferrite was formed, less carbon was available to enrich the austenite in 5140, and it did not harden when refrigerated.

5. In all the steels examined an acicular type of ferrite termed para-ferrite formed prior to bainite at cooling rates less than critical. This was readily observed in 4340 and 9840, but it was obscured by overlapping pro-eutectoid ferrite in 86 B 40, 5140 and 4140.

PAUL G. NELSON

Sigma in Cr-Co-Mo Alloys

Digest of "Effect of Sigma Phase on Cobalt-Chromium-Molybdenum Base Alloys", by Ronald Silverman, William Arbiter and Frank Hodi. ⊕ Preprint No. 31, 1956.

THE BRITTLE intermetallic sigma phase which occurs in various alloy systems is a constant challenge to metallurgists. Here it was studied in the "Vitallium" or "Stellite 21" family to see if increasing amounts would stiffen this alloy system at 1800° F. and to determine associated properties at that temperature.

From the basic alloy with 28% Cr, 67% Co, and 6% Mo, which is substantially sigma-free, five alloys ranging up to 43% Cr, 42% Co and 15% Mo were made, attaining about 15, 28, 39, 63, and 76% of the sigma phase. (Incidental elements were about 0.40% C, from 0.31 to 0.70% N, and about 2% each of nickel and iron.)

Density decreased from 8.30 g. per cc. with 15% sigma to 8.17 with 76% sigma, while resistivity increased slightly (101 to 107 microhm-cm.). Hardness increased from about Rockwell A-60 to A-82, while impact resistance fell sharply. These trends were not much influenced by thermal history.

Five heat treatments were imposed: (*a*) as cast, (*b*) solution

Sigma Phase . . .

treated at 1250° C. (2280° F.) for 0.5 hr., (*c*) 1250° C. for 24 hr., (*d*) aging at 730° C. (1345° F.) for 50 hr. after treatment (*b*), and (*e*) aging 50 hr. at 730° C. without previous solution treatments. All heat treatments ended with air cooling. The 76% sigma alloy was softened by solution treatment, but hardening occurred with 63% sigma. The 39% sigma alloy was erratic; alloys with 28 and 15% sigma were softened by the high-temperature treatments and hardened by the low-temperature.

Energy absorbed in the N.A.C.A. drop impact test ranged from 33 in-lb. down to 0.5. Aging treatments caused precipitates along crystallographic planes and markedly decreased impact resistance.

Many interesting microstructures appeared. Besides the basic alpha solid solution and sigma, the $M_{23}C_6$, Cr_7C_3, CrN, and beta phases were probably present. Lamellar, massive, acicular, and grain-boundary habits were noted. The lamellae were suspected of being a ternery or binary eutectoid ($Cr_{23}C_6$ + Co-rich solid solution); they are most prevalent in the high-sigma alloys and were substantially eliminated by solution heat treatment. Oriented precipitation patterns followed the aging during treatment (*d*); they are grid-like and appear to be related to sigma content.

Stress-rupture tests at 1800° F. and 10,000 psi. appeared to give quite significant data. The maxima were 28 hr. (25% reduction of area) for 15% sigma, as cast; and 34 hr. (10.3% reduction of area) for 28% sigma after aging treatment (*c*). With 39% sigma or more the longest life was 7 hr. Ductility was decreased by aging, but creep resistance was not enhanced. Since the Vitallium or Stellite 21 (sigma-free) has an expectancy of about 50 hr., sigma seems detrimental to the useful high-temperature strength as well as to toughness. (The authors had trouble confirming this figure from one commercial heat. However, the specimens were badly twisted in testing and the discrepancy was assigned to either faulty material or faulty equipment.)

Therefore better hot strength cannot be secured in this system through sigma formation.

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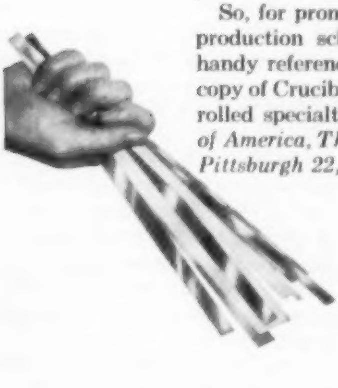

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Notch Toughness of Ingot Iron

Digest of "The Effect of Sub-Boundaries and Carbide Distribution on the Notch Toughness of an Ingot Iron", by J. C. Danko and R. D. Stout. ⊕ Preprint No. 5, 1956.

THIS PAPER studies the effect of subboundaries and carbide distribution on the notch toughness of a commercial ingot iron. By changing the heat treatment, the ferrite grain size, the subgrain size and the carbide distribution were varied prior to testing. Annealing temperatures ranged between 1650 and 2200° F. to vary the primary ferrite grain size; cooling rates (furnace, air, or water quenching) gave differences in subgrain size. Carbide distribution was changed by solution treatment at 1300° F., furnace cooling or quenching, and aging at 400° F.

Annealed samples had a transition temperature about 100° F. higher than the quenched and aged ones – provided average grain size of the primary ferrite is the same. With a constant subgrain size in the ferrite, an increase in the size of the primary ferrite by one grain size number raises the Charpy V-notch transition temperature approximately 20° F.

The 100° F. difference noted at the beginning of the last paragraph is a reflection of a different carbide distribution. In the annealed specimens, discontinuous carbide networks exist in the ferrite grain boundaries and fine discrete carbide particles in the subboundaries. On the other hand, the solution-treated and aged material contained carbides throughout the matrix and subboundaries, the former in the form of platelets. Difference in the notch toughness after the two heat treatments is attributable to this carbide distribution and segregation at the subboundaries.

Subgrain size is independent of austenitizing temperature, but decreases with faster cooling rates. After solution treatment and aging, the pre-annealed ingot iron had a transition temperature 80° F. lower than a prequenched sample of the same primary grain size. In samples furnace cooled after reheating to 1300° F., the difference was 30° F.

Other facts discovered in this investigation include the finding that

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in the normalized condition (air cooled) the ferrite and subgrain size was coarser than after water quenching. After solution and aging, the prenormalized iron had a transition temperature 35° F. (17° C.) lower than the prequenched, and 45° F. (25° C.) higher than the preannealed iron.

In the furnace cooled condition, the quenched iron embrittles at a lower temperature than the normalized iron. If a correction is made for the difference in ferrite grain size, the normalized iron should have a transition temperature falling between that of the annealed and the quenched iron. Thus, the effect of subboundaries is to raise the transition temperature appreciably in solution treated and aged ingot iron but the effect is decreased in the furnace cooled condition.

In summary, low impact transition temperatures in ingot iron are favored by a fine ferrite grain size, coarse subgrain size, and by a reduction of grain boundary and subboundary carbides by the proper heat treatment.

G. J. Salvaccio

Deformation in Iron Crystals

Digest of "Slip, Twinning and Fracture in Single Crystals of Iron", by J. J. Cox, G. T. Horne, and R. F. Mehl. ⊕ Preprint No. 1, 1956.

This paper gives data on the slip, twinning and fracture of single crystals of decarburized mild steel at temperatures from 390° to −320° F. The original material consisted of a silicon killed, hot rolled S.A.E. 1008 steel, decarburized and then strain-annealed to large single crystals. Each crystal was properly oriented in a goniometer before straining 4%. Laue photographs were taken before and after deformation. The orientation and optical measurement of slip traces were plotted on a standard (001) projection.

To study slip in this range of temperature, the angle between the (101) and the maximum resolved shear stress plane containing the slip directions, and the angle between the (101) and the position of the

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Iron Crystals . . .

integrated glide ellipse was measured. (The latter is that plane defined by the average slope of the wavy slip lines observed on the circumference of the crystal.) This integrated glide ellipse occupied various positions in the <111> zone, deviations from the planes {110}, {112} and {123} being real. The distribution of the glide ellipse along the <111> was markedly affected by temperature; lower temperature increased the shearing strengths near {112} more than {110}, thus favoring {110} slip regardless of distribution of the applied stress.

The authors conclude that the critical shear stress law is a valid criterion for the initiation of slip. The stress remains about constant from +32° to +392° F. but increases rapidly as the metal is cooled from +32° to −321° F.

Twins were studied at −321° F. The critical resolved shear stress for twinning was calculated from the load at which an initial burst of twins appeared, accompanied by a loud report. A mean value of 14,100 psi. was found for unstrained crystals, and 20,800 psi. for crystals prestrained at 70° F. The higher values for the latter indicated that high-temperature slip may inhibit twinning at low temperatures. The initial twin plane was always the one predicted by the critical shear stress theory, but the direction of strain in tension or compression must also be considered. Twinning always accompanies the fracture process and occurs adjacent to the fracture surfaces.

Fractographic examination indicated that brittle fracture is a combination of shear and parting, the proportion of shear being increased by increased angle between the {001} pole and tensile axis, and by prestraining.

G. J. Salvaggio

Tougher Iron-Aluminum Alloys

Digest of "The Mechanical Properties of Iron-Aluminum Alloys", by W. Justusson, V. F. Zackay and E. R. Morgan. Preprint No. 36, 1956.

Iron-aluminum alloys have unique electrical, magnetic and refractory properties, but their commercial development has been retarded by their apparent room temperature brittleness. Melting and casting practice, hot working, heat treatment and the effect of alloying elements were therefore examined .

Alloys were made in an induction furnace under vacuum from electrolytic iron. Heats were deoxidized with carbon, held 10 min. under a vacuum of one micron or less, and high-purity aluminum added. All the heats were cast into steel molds at 2900° F. or less to maintain a fine grain size. After slow cooling and reheating to 1800° F., they were hot rolled to ⅝-in. rounds, often finishing below 1000° F.

A series of ternary alloys containing 0.5% titanium was also made. The titanium was to form a stable carbide with any excess carbon from the deoxidation reaction, and so eliminate any embrittling complex

Fe-Al Alloys . . .

carbides of the iron-aluminum-carbon system.

Prior to testing, the samples were given a recrystallization anneal of 1 hr. at 1400° F., followed either by furnace cooling or water quenching. The presence or absence of a superlattice of the iron-aluminum system was then determined by electrical resistance measurements.

Room-temperature tensile tests show an increase in yield and tensile strength with increasing aluminum in the binary alloys up to about 15 to 16%, whereafter a rapid fall in strength is observed. The maximum in yield and tensile strengths occurs close to the stoichiometric composition of the Fe_3Al superlattice. A decrease in ductility with aluminum content up to 10% was noted for samples either slowly cooled or quenched. At higher aluminum levels the furnace cooled alloys lost ductility more rapidly – probably because of the superlattice remaining after this heat treatment.

The ternary iron-aluminum-titanium alloys are somewhat different. When yield strength is plotted against aluminum content, the curve for the quenched alloys has a flat plateau rather than a sharp maximum. Tensile strength sharply drops at about 14% aluminum in the quenched alloys and at about 12% in the furnace cooled ones. A considerable difference is noted in ductility after the two heat treatments: The quenched alloys have high ductility up to 10% aluminum and a little higher aluminum makes them brittle. The furnace cooled alloys show a gradual decrease in elongation from a value of 40% for 8% aluminum to zero at 12% aluminum.

In alloys containing 10% aluminum or more, ductility may be improved by quenching from above 950° F. – the critical ordering temperature for the Fe_3Al superlattice. Better ductility also follows quenching in oil rather than water, which minimizes quenching stresses.

It would appear, therefore, that the difficulties ordinarily encountered in processing iron-aluminum alloys can be lessened by controlling the interstitial elements oxygen and carbon, control of grain size, and heat treatment schedule.

G. J. SALVAGGIO

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Advantages of Alpha Versus Beta Titanium at High Temperatures

Digest of "Relative High-Temperature Properties of the Hexagonal Close-Packed and Body-Centered-Cubic Structures in Iodide Titanium", by John Lunsford and Nicholas J. Grant. ⊕ Preprint No. 9, 1956.

PHYSICAL PROPERTIES of titanium indicate that it may be a very satisfactory base for high-temperature alloys. However, since it undergoes a phase change at 1620° F. one should know which phase is more suitable. Hence this study of the two phases, their high-temperature behavior, fracture, and testing techniques.

Arc-melted iodide titanium was furnished by the National Research Corp. in 8-lb. ingots. These were forged at 1800° F. to 1-in. square bars, swaged to 5/16-in. rounds, and annealed 2 hr. at 1600° F. in evacuated Vycor capsules. Specimens 0.160 in. diameter and 1-in. gage length were subjected to creep-rupture tests at temperatures between 1000° F. and 1990° F.

The alpha phase (hexagonal) possessed much greater strength and creep resistance than beta (cubic) but the latter had better ductility, indicating that it would provide the better high-temperature matrix.

During creep-rupture tests recrystallization occurred after 1 hr. at 1000° F. In contrast to this, a statically tested specimen, cold worked to 90% reduction in area, required 2 hr. at 1200° F. Recrystallization in the creep specimen occurred around a lenticular nucleus which remained distinct from the new matrix. Since this nucleus was unstable at 1000° F. and was not found in the annealed condition, it was assumed to be a deformation product — namely, the 1012 twin.

Another finding was that heating titanium softened it at first (due to a tempering effect) but if heating were continued, hardness would subsequently increase. This was attributed to oxidation alloying. It strengthened the material to such an extent that creep appeared to have ceased completely between 1400 and 1600° F. Above 1600° F. the alloying was so rapid that the specimens had to be

Titanium . . .

placed in a superheated furnace for a short time in order to minimize the alloying effect. This preheat time was too short to transform all the alpha in the specimens tested at 1650° F., and therefore gave erratic results since transformation was taking place during the test. This was verified by metallography. It was later found that 0.1 hr. at 1650° F. was required for complete transformation, and no untransformed alpha was found at higher temperatures.

BERNARD TROCK

Hot Hardness of Iron and Steel of Super Purity

Digest of "The Temperature Dependence of the Hardness of 'Pure' Iron and Various Ferritic Steels", by F. Garofalo, G. V. Smith and D. C. Marsden. Preprint No. 15, 1956.

HARDNESS of steels, as it varies with temperature, is related to the corresponding tensile strengths and creep and rupture strengths. Also, hot hardness is known to be sensitive to such phenomena as strain aging, recovery and recrystallization, and phase changes. While the hardness of pure metals (expressed in kg. per sq. mm.) follows an experimental relationship where H is hardness, T is absolute temperature and A and B constants, "pure" iron and commercial steels at elevated temperatures have been meagerly investigated in this respect. This deficiency has now been removed by the paper under review. It presents data on the change in hardness with temperature up to 1200° F. of "pure" iron, low-carbon commercial steels, and chromium steels from 1 to 27% chromium. Some of the latter contained molybdenum, silicon and titanium.

The experimental results for most "pure" metals show that hardness continually decreases with increasing temperature. By plotting log hardness against absolute temperature, straight lines result. This was not found in the present report, and the deviation was associated with a strain aging reaction caused by the small amounts of nitrogen and carbon which the metal contained. This

Hot Hardness . . .

was true for "pure" iron, low-carbon commercial steels, 1% Cr steel with 0.5% Mo, and the 17% and 27% Cr commercial steels. The curves for these materials exhibited hardness peaks at varying temperatures which were associated with strain aging reactions. On the other hand, the 8% Cr, 8% Cr-Mo and the 12% Cr steels had *constant* hardness over a 200° F. temperature range; this was also traced to strain aging.

Purification of a low-carbon steel in wet hydrogen and suitable heat treatment of the 5%, 8% and 17% Cr steels containing titanium or silicon, eliminated these anomalies; thereupon the hardness-temperature curves are similar to those of typical nonferrous metals in the pure state.

Some tests were made on samples prestrained 5% in tension at 80° F. and aged 1 hr. at 400 or 600° F. When tested in tension at 80° F., the 1% Cr steel with 0.5% Mo, and the 17% and 27% Cr steels had stress-strain curves showing discontinuous yielding and a measurable increase in flow stress.

A two-step hot hardness test also verified the assumption that steels showing a hardness peak or a constant hardness over a temperature range are susceptible to strain aging.

D. J. Carney

Axial Fatigue and Stress-Rupture in Alpha-Beta Brass

Digest of "Effect of Dispersion of Alpha Phase on the High Temperature Fatigue Properties of Alpha-Beta Brass", by J. E. Breen and Joseph R. Lane. Preprint, No. 39, 1956.

Many publications deal with the effects of dispersion of one phase in a multiphase alloy on properties at room temperature, and on creep and stress-rupture. In this paper high-temperature fatigue and stress-rupture were studied.

Sections ⅝ in. round by 3 in. long of alpha-beta brass (60.15% Cu, 0.70% Sn, 0.10% max. Pb) were quenched in water from 1520° F. to produce an all-beta structure supersaturated with alpha, and then reheated or aged at 500 to 1300° F. to obtain a wide variation in the dispersion of alpha. After this last heating, half of the specimens were air cooled; the remainder were furnace cooled. The mean free path between alpha grains in the beta matrix was used as a measure of dispersion. Its logarithm was determined and found to be a straight-line function of the aging temperature.

Fatigue tests were made with specimens at 500, 600 or 700° F. in a Sonntag axial loading machine. The mean load was maintained constant during the test, and the dynamic loading was about 37.5% of the static or mean load. The specimens gradually elongated during the test; this elongation was measured and is called "tensile fatigue creep". Stress-rupture tests were run at the same temperatures and equivalent mean loads. Representative tests are shown below:

Temperature	Stress, Psi.
Tensile fatigue	
700 °F.	3000 ± 1100
600	6000 ± 2250
500	11,000 ± 4125
Stress-rupture	
700 °F.	3000
600	6000
500	11,000

1. Tensile fatigue creep rates decreased continuously with decrease in mean free path between alpha grains at all temperatures. In stress-rupture this was true only at 500°;

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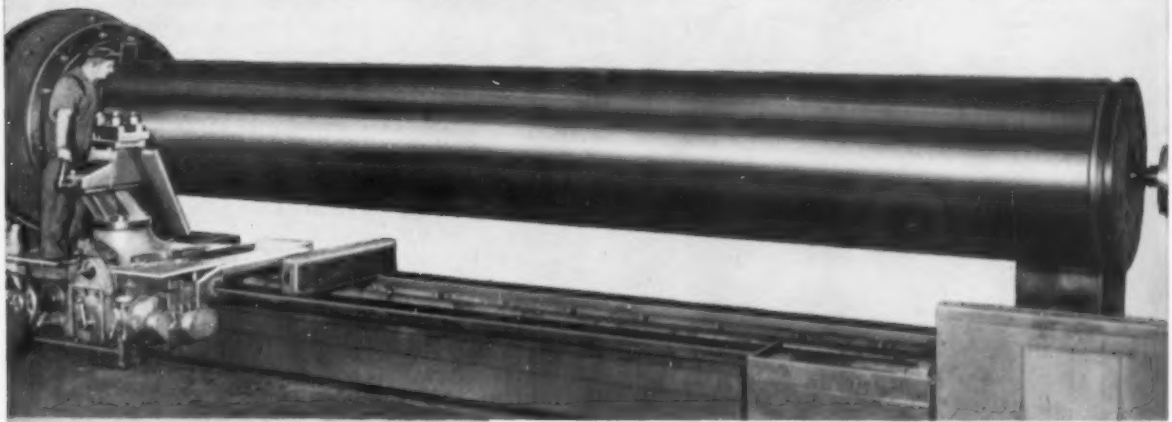

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Fatigue of Brass . . .

at higher temperatures an intermediate dispersion had the highest creep rate.

2. In both tensile fatigue and stress-rupture at 500° F. ductility decreases continuously with decrease in mean free path between alpha grains. At 600 and 700° F. the ductility is at a maximum with intermediate dispersion. Ductility is generally greater in tensile fatigue than in stress-rupture tests.

3. Specimen life is not simply related to dispersion because it depends on creep rate and ductility.

4. At 500° F. the scatter in the data was greater than at higher temperatures.

5. The mode of fracture is not dependent on the dispersion of phases in the microstructure. In tensile fatigue it changes from transgranular to intergranular in the range between 500 and 700° F. All stress-rupture fractures were intergranular.

PAUL G. NELSON

New Dynamic Test

Digest of "Dynamic Bi-Axial Stress-Strain Characteristics of Aluminum and Mild Steel", by George Girard and Ralph Papirno. Ⓢ Preprint No. 2, 1956.

THIS PAPER uses a rather unusual approach which may become a tool for evaluating materials in the future.

An impact tube (comprising three pressure chambers, a rupture disk and a specimen) constitutes the major portion of the test assembly. The specimen is a 6-in. disk of thin sheet, in the range of 5 to 15 mils. This is mounted between two of the pressure chambers and both are evacuated. Attached to one of the chambers, and separated by a rupture diaphragm, is a third chamber in which any desired pressure can be pumped. By rupturing the seal, an instantaneous pressure differential is applied to the sheet under test, causing it to bulge and yield under an essentially constant load, continuously applied.

An attached oscilloscope simultaneously traces the timing wave, the time cycle during which the load is applied, stress curves and strain magnitudes (the latter measured

These intricate, close-tolerance collets weigh less than 10 pounds—are worth nearly $800 each. The manufacturer states: "Our experience with various collet steels proves Crucible collet steel to be superior for flexibility and ability to hold its shape during heat treatment."

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These collets are used in machining the anchoring end of jet engine turbine blades, while locating the part from reference points on the airfoil section of the blade. It's a job that demands a steel which will not distort during heat treatment. The collet head is heated to Rockwell 58-60 C—the body tempered to 35-38 C.

The steel used is a special Crucible non-warping alloy collet grade. The collet manufacturer, Balas Collet Mfg. Co., Cleveland, Ohio, reports: *The extreme accuracy built into these collets while they are still in the soft state shows less than .0005" distortion on any dimension after heat treatment.*

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Dynamic Test . . .

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A theoretical analysis shows how to determine stresses and strains in a two-dimensional field shaped like a spheroidal ellipse. Data and theory also compare the results of dynamic and static tests, there being essentially no difference in the dome shape or stress pattern. With thin membranes the third stress dimension may be ignored.

Data on iron and aluminum samples are compared with uniaxial values such as those from tensile impact and short-time tensile tests. Significant observations include the following:

1. In both metals tested, marked increases in ultimate tensile strength resulted from short impact loadings – on the order of microseconds.

2. Upper and lower yield points were readily discernible in iron. The upper yield point, measured as 50,000 psi. under static loading, increases to 90,000 psi. during loading at a rate of 10^7 psi. per sec.

3. Iron deforms under dynamic loading in a completely elastic manner until the upper yield point is reached. At this point Lüders lines form, and there is a sharp decrease in the central radius of curvature of the diaphragm. Equilibrium between the applied stress and strain rate requires more than 35 milliseconds after maximum load is applied.

4. Catastrophic failures in steel disks sometimes occurred at stresses much lower than would be predicted by uniaxial test data; the mechanism includes formation of Lüders lines and subsequent thinning to the point of fracture. In general, Lüders lines are oriented parallel to the rolling direction. To the authors, some of the catastrophic failures suggest the brittle failures which have occurred in rigid plate structures used by industry.

These preliminary results indicate that the biaxial stress evaluation test may be more reliable for screening materials for complex structures made of sheet and plate than the conventional tensile testing. This important testing device seems worthy of careful evaluation by everyone concerned with dynamic stresses in equipment components.

J. L. Wyatt

Effect of Bainite on Strength

Digest of "The Influence of Bainite on Mechanical Properties", by R. F. Hehemann, V. Luhanov and A. R. Troiano. ⊕ Preprint No. 16, 1956.

When 4340 steel is heat treated to high strength levels, the presence of high-temperature bainite lowers the yield strength, ductility and impact energy. The reduction of these properties increases as the amount of the bainite increases. However, as the temperature of formation of the bainite is lowered, reduction of the mechanical properties becomes less severe until at reaction temperatures near the M_s, the ductility and toughness of the mixed microstructure are equivalent or slightly superior to the quenched and tempered microstructures.

The detrimental effect of high-temperature soft bainite on the mechanical properties is believed to be associated primarily with the hardness differential between bainite and tempered martensite. The same loss in ductility is observed with mixtures of soft and hard martensite at the higher strength levels. This behavior does not appear to involve a soft grain boundary network.

While there is some loss of ductility when high-temperature bainite is present in the microstructure, it is relatively low for amounts up to about 15%. Thus, a heat treatment involving the formation of small amounts of high-temperature bainite prior to quenching for martensite appears to be feasible.

H. J. Elmendorf

Silicon Improves Ultra High-Strength Steels

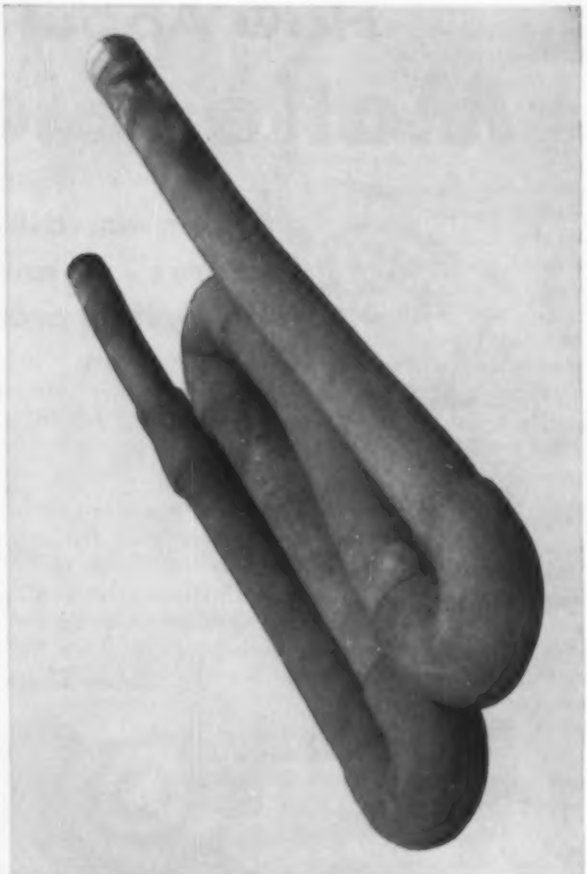
Digest of "Effect of Silicon on Transverse Properties and on Retained Austenite Content of High-Strength Steels", by John Vajda, John J. Hauser and Cyril Wells. ⊕ Preprint No. 24, 1956.

Low transverse ductility limits the usefulness of steel forgings heat treated to ultra high strength. Some alloy steels with silicon additions have their tensile strengths significantly increased with no attendant decrease in ductility or notch toughness when heat treated to strengths in the range of 260,000 to 300,000 psi.

The present investigation was intended to supplement available information with data on transverse mechanical properties as they vary with silicon, and to correlate these properties with the microstructure. Three Ni-Cr-Mo steels of the A.I.S.I. 4340 type containing 1.25, 1.0 and 1.5% silicon were investigated over the wide range of quenched and tempered structures existing in end-quenched 7-in. rounds.

Increased hardenability and resistance to softening during tempering, which had been reported by other investigators in steels with extra silicon contents, were confirmed by the present tests. Silicon considerably increased the amounts of retained austenite, especially in the more slowly cooled portions, where as much as 27% austenite was found in the 4340 plus 1.5% silicon steel.

This unretouched photograph shows deterioration of 25-12 alloy radiant tube after 10 months service.



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(The base alloy with 0.25% Si contained 4% austenite under similar conditions.) No significant detrimental effect of this much retained austenite on the mechanical properties was observed. Improvement in the transverse tensile and yield strengths on tempering the high-silicon steel at 500 and 600° F. was thought to be due to stress relief, since no significant additional amount of austenite transformed at those tempering temperatures.

The most favorable combinations of transverse strength and ductility were obtained with the highest silicon steel after tempering at 500° F. The results indicated that aircraft quality A.I.S.I. 4340 to which 1.5% silicon has been added can be tempered as high as 500° F. to give in fully quenched forgings a tensile strength of about 280,000 psi., together with relatively high transverse reduction of area (15 to 20%) and transverse notched impact values of 10 to 12 ft-lb.

H. Y. Hunsicker

Impact Properties of Leaded Steels

Digest of "Impact Characteristics and Mechanical Properties of Leaded and Non-Leaded C-1050 and C-1141 Steels", by A. P. Weaver. Preprint No. 22, 1956.

Although the effect of lead additions to steel on hardness and tensile properties is well known, adequate information about Charpy impact properties has not heretofore been available.

Two alloys, C 1050 and C 1141, were studied. Two consecutive ingots were chosen from the middle portion of one heat of C 1141 and from two heats of C 1050, one made by fine-grain and the other by coarse-grain practice. Lead was added (0.20 to 0.30%) to one ingot from each heat.

Brinell hardness tests, tensile tests and Charpy V-notch impact tests were made on all materials as hot rolled and also on the C 1141 steel in the cold drawn condition. Samples were also tested after normalizing and after quenching and tempering.

Leaded Steels . . .

There was little or no difference in tensile properties of any of the alloys because of the lead additions. Hardness of the C 1141 was not affected by lead but there was a slight reduction in hardness in the leaded C 1050 samples.

In virtually all samples, the Charpy V-notch impact transition temperatures were lower for the leaded steels than the nonleaded steels of the same grade and composition. The impact energies of the leaded materials were higher at temperatures below some point above or in the upper portion of the transition temperature range. The nonleaded materials had the higher impact energies above the transition range. Normalizing increased the energy required to break the impact test specimens and a quench and temper resulted in even higher impact energies and lower transition temperatures.

Brittle fracture curves were included in the report and were in agreement in nearly all instances with the impact energy curves. At a specific temperature, the nonleaded steels show a higher percentage of brittle fracture and higher transition ranges than the leaded alloys. The leaded steels as hot rolled have finer grain structure than corresponding nonleaded samples.

E. S. Rider

Ductile Chromium Metal

Digest of "Mechanical Properties of Swaged Iodide-Base Chromium and Chromium Alloys", by D. J. Maykuth and R. I. Jaffee. Preprint No. 38, 1956.

Considerable interest in ductile chromium has been shown for several years. Since chromium is usually quite brittle, much effort has been devoted to preparation of the metal in a high degree of purity. The cause of room-temperature brittleness has also been controversial; suggestions range from transition temperature effects to grain boundary precipitation. Chromium and chromium-base alloys are of interest for gas turbine applications because of their high strength and good corrosion resistance.

By modifications to the van Arkel process, chromium has recently been produced containing less than 5 ppm. oxygen and nitrogen. Data on this high-purity chromium and alloys made from it are reported.

Crystal bar chromium was melted on a copper hearth, hot forged at 1250° C. (2280° F.) and sheathed in iron and swaged to rod at 800° C. (1475° F.). A section annealed 1 hr. at 600° C. (1110° F.) and water quenched was machined into a tensile bar; this had ultimate strength of 60,000 psi., 44% elongation in ¾-in. gage length, and 78% reduction in area. This is the greatest ductility ever reported for chromium metal.

A sample of the same rod, after recrystallizing at 816° C. (1500° F.), had tensile strength of 41,000 psi., no elongation or reduction in area, and broke with brittle fracture. Dynamic measurements showed an elastic modulus of 42,000,000 psi. at room temperature, decreasing to 36,000,000 at 800° C. (1475° F.).

Alloys of chromium containing 40% and 50% iron showed decreasing strengths and increasing elongations with increasing alloy content in the forged and swaged condition. Nickel alloys exhibited similar trends; however, the 40% nickel, 60% chromium has a vanishing amount of ductility.

The modulus of elasticity of both alloy systems was determined as a function of temperature. It ranged from 31,000,000 to 33,500,000 psi. at room temperature and 22,000,000 to 25,000,000 psi. at 1500° F.

J. L. Wyatt

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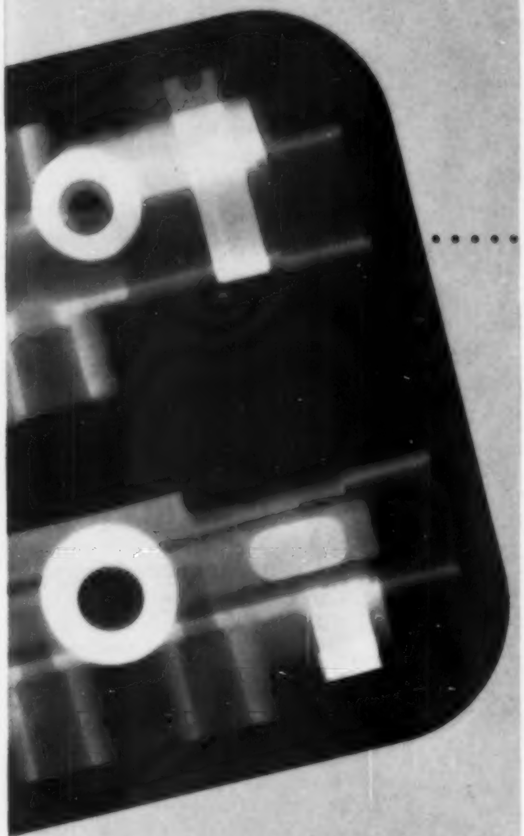

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"Brittle" Fracture in Gray Iron

Digest of "The Deformation and Rupture of Gray Cast Iron", by W. R. Clough and M. E. Shank. ● Preprint No. 8, 1956.

All gray cast irons have small ductility in tension, a compressive strength 2½ to 4 times the tensile strength, and no "proportional limit" because tensile stress is not proportional to strain at any loading. The internal notching effect of graphite doubtless introduces severe stress concentrations at the thin flakes. To study some of these phenomena, the authors determined some mechanical properties of thin-walled specimens and others under combined stress. Microscopic deformation was also examined, and density measured by immersion methods.

A cast iron of the following analysis was used: total carbon 3.0%, silicon 1.25%, manganese 0.60%, sulphur 0.015% and phosphorus 0.05%.

Most of the specimens had an almost 100% pearlitic matrix. Some specimens in which the microstructural effects of stress on deformation were studied under the microscope were heated 12 hr. at 1300° F. to an entirely ferritic matrix.

Tubular specimens, 1.375-in. ID and wall thickness of 0.050 in., were tested in tension while under internal pressure. Compression tests were also made on threaded specimens held rigidly on the ends by plates so that a tangential or hoop stress was superimposed. Stress ratios varied widely. Strains were measured by Type A-8 resistance strain gages.

The microscope revealed deformation in the matrix of ferritic iron at loads as low as 3000 psi. Axial stress-strain curves of the tensile tests and the equibiaxial tension tests (as well as all five of the tangential strain curves) were practically identical. This implies that maximum strain is determined only by maximum tensile stress. For such to be true, lateral contraction in the plastic range must have little effect.

Results of all tests were summarized as follows:

1. Gray iron plastically deforms at very low stress levels because of stress concentration at internal notches. Photomicrographs show de-

Gray Iron . . .

formation at stress levels as low as 3000 psi. Stress is not proportional to strain at *any* stress level – the material is not "elastic".

2. Gray iron decreases in density when under stress. This volume change is greater in tension but also is present in compression. Graphite flakes apparently open up along planes approximately perpendicular to the applied stress. This stress is a tensile stress, which occurs in certain directions even when externally applied stresses are compressive.

3. Under combined tension-tension stress, the greatest macroscopic strain is a function of the greatest tensile stress. The larger part of the strain measured by the gages is not the small strain of the matrix but that resulting from opening up of graphite flakes. This also accounts for the small lateral contraction of cast iron (about 0.28%) at tensile fracture. Density decreases, which accounts for lateral contraction being less than the accepted figure of 0.5.

4. Although the fracture of gray iron is similar to that of a fully brittle material, it is actually preceded by extensive but highly localized plastic deformation. Rupture results from interconnected ductile fractures across the ferrite and by splitting across graphite flakes.

5. Various fracture criteria suggested by other investigators do not adequately explain the mechanism of fracture of gray cast iron, which depends upon the solution of the problem of randomly spaced saucer-like particles in a plastic medium.

PAUL G. NELSON

Microstructure of 18-8 Ti

Digest of "Metallography of Titanium-Stabilized 18-8 Stainless Steels", by T. V. Simpkinson. Preprint No. 29, 1956.

THE MICROSTRUCTURE of A.I.S.I. Type 321 normally consists of an austenite matrix with nonmetallic inclusions which are largely TiC and TiC-TiN solid solution phases, plus ferrite and sigma, depending on chemical composition and prior thermal history. This paper illustrates fully the many features of these microstructures.

The material studied was an induction furnace heat cast into a keel block. A vertical slice was forged into a bar with reduction of ten to one. Most of the photomicrographs are from the cast material, because the amount and distribution of the phases are more favorable in the cast state.

Time and temperature required for formation and solution of chromium carbide and the preferential formation of titanium carbide are illustrated together with the proper etching techniques necessary to distinguish the phases. The fine dot-like carbide occurring in cast Type 321 is investigated; the author concludes that it is chromium carbide rather than fine sigma.

Sigma phases in cast and wrought samples are described separately. The effects of heat treatment on transformation and solution of sigma are illustrated. The effect of alumi-

Tool Steel Topics

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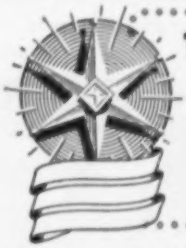
BETHLEHEM TOOL STEEL ENGINEER SAYS:

Remove all the "Bark" from Liquid-Quenched Tools

Most users of tool steel realize that it is necessary to remove the "bark" (scaled and decarburized outer surface) from tool-steel bars in order to obtain full, uniform hardness in heat-treatment. If this area is not removed, low hardness will result because of the low carbon content of the decarburized metal. It is not always recognized that this procedure is necessary on tools which are to be liquid quenched, even though portions of the tool do not constitute working surfaces.

If tools are to be liquid quenched, all the bark must be removed to avoid excessively high quenching stresses which could cause cracking of tools during hardening. Low carbon areas on the surface transform during hardening at a different time than the higher carbon interior. This sets up additional stress which, added to the high thermal stresses from quenching, could cause cracking. Air-hardened tools can tolerate bark on non-working areas because of the low hardening stresses in air hardening. But with liquid-quenched tools there are no exceptions — remove all the bark.



TOOL STEEL MOVIE WINS ANOTHER AWARD

"Teamwork," Bethlehem's new motion picture on tool steel, received a second film award, a silver reel symbolic of excellence, at the recent American Film Assembly competition in Chicago.

The 16-mm, 30-minute color film explains the manufacture, quality control and heat-treatment of Bethlehem tool steels. It is available for showings to machinists, heat-treaters, die makers and tool manufacturers. To see the film, write to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

Microstructure . . .

num content on sigma formation is noted. It was shown that the commonly recommended stabilizing heat treatment of 1 to 2 hr. at 1550° F. transforms the grain-boundary ferrite largely to sigma and new austenite. 1650° F. is usually too hot for sigma formation.

A few of the conclusions are:

1. In the as-cast condition some sigma phase is present in certain ferrite islands located at grain boundaries, but no sigma is detected in ferrite islands located within the austenite grains.

2. Chromium carbide is largely dissolved by 1 to 2 hr. at 1650° F., or in a shorter time at higher temperature.

3. A temperature of 1750° F. or higher is necessary to dissolve all of the sigma phase during 30-min. heating.

4. During *initial* heating of cast Type 321 at 1650 to 1750° F. much TiC is precipitated in a heavy dispersion. Even when the *initial* heating temperature of the casting was considerably higher (up to about 2100° F.), such precipitation occurred, the amount decreasing with the higher temperature.

5. The heat treatment commonly specified for testing susceptibility of 18-8 grades to "sensitization", namely 1 to 2 hr. at 1200 to 1250° F., produced a small amount of sigma. However, it does not seem likely that this would have an important influence on corrosion.

D. J. Carney

Changes in Modulus With Alloying

Digest of "The Influence of Alloying on the Elastic Modulus of Titanium Alloys", by W. H. Graft, D. W. Levinson and W. Rostoker. Preprint No. 10, 1956.

Structural materials for aircraft applications should have high ratios of strength and modulus of elasticity to density. Much work has been done to improve strength-weight ratios, and in this paper the feasibility of increasing the modulus-to-density ratio of titanium by alloying was investigated.

The dynamic modulus of elasticity

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Modulus of Ti . . .

was measured at temperatures between 70 and 750° F., using an electrostatic device. A bar of uniform cross section and length, L, was suspended by its middle and vibrated electrostatically from one end by a sine wave generator. At the resonant frequency for the fundamental vibration, f_n, the bar ends vibrate through large amplitudes while the center is a node. This is readily detected. The absolute value of the modulus may be calculated from the equation $E=4\ L^2f_n{}^2d$, where d is the density.

The variation of E or E/d with temperature was found to be linear. Thus, the modulus of elasticity of unalloyed titanium decreased from 16.2×10^6 psi. at room temperature to 12.6×10^6 psi at 750°. Beta titanium was found to have a lower modulus of about 12 to 14×10^6 psi. at room temperature, as measured on a group of alloys which retained soft beta after quenching.

Aluminum up to 8% was found to increase the modulus and decrease the density, in agreement with earlier findings. Oxygen and nitrogen had little effect up to 0.6 and 0.7% respectively – well beyond the impurity limits for these interstitial elements.

Compound-forming elements, particularly up to 2.7% carbon and 1.4% boron, had a potent effect in increasing the modulus of elasticity to 20×10^6 psi. The other compound-formers, such as silicon up to 1.6%, beryllium up to 1.4%, and copper up to 11.5%, increased the modulus to about 17.3×10^6 psi. None of these elements increased E/d significantly over that for the 8% aluminum alloy (11.8 at 70° F., 10.6 at 500° F., and 10.0 at 750° F.). Effects of solid-solution alloying are additive to that of compound formation. Thus an alloy of 6% Al and 0.6% C had a modulus of 19.2×10^6 psi. at 70° F.

The modulus of alpha-prime in an alloy with 10% vanadium was rather low, about 9×10^6 psi. The presence of omega, the transition phase found in low-temperature aging of beta, was associated with a high modulus of about 20×10^6 psi. In alpha-beta alloys, the modulus values were found to be intermediate between those of alpha and beta titanium and to vary with the relative percentages of each. R. I. JAFFEE

Mechanical Equation of State

Digest of "Effect of Strain Rate and Temperature on the Plastic Deformation of High-Purity Aluminum", by T. A. Trozera, O. D. Sherby and J. E. Dorn. ● Preprint No. 4, 1956.

THE MECHANICAL equation of state, as originally proposed by Zener and Hollomon, suggested that the flow stress is a function of strain and of a second term Z. Z is the product of strain rate and an exponential function of the activation energy for plastic flow. Qualitatively, this relationship suggests that greater flow stresses are found as the strain and strain rate increase and as the temperature decreases.

Dorn had shown that this mechanical equation of state is not strictly valid, since the flow stress depends also on previous plastic flow as well as the instantaneous strain and strain rate. In the present work, they attempt to determine if flow stress is a single valued function of strain when Z is kept constant. In this case the activation energy for plastic flow need not necessarily be constant, and a mechanical equation of state is not implied.

Aluminum sheet of 99.997% purity was machined into tensile specimens 0.100 in. thick, 0.250 in. wide and 1-in. gage section, and annealed 50 min. at 510° C. (950° F.) to equiaxed grain of about 1 mm. average diameter. These specimens were tested from −195 to 545° C. (−320 to 1015° F.) at four strain rates: 0.0035, 0.169, 7.0, and 600 per hr. True stress-strain curves were obtained for each set of conditions, and formed a nonintersecting homologous series of curves.

It was found that the curves of high strain rate and high temperature often overlapped curves of low strain rate and low temperature, showing that to some degree strain rate and temperature could be interchanged. The analysis of the stress-strain data was rather masterful. First, the curves were replotted in terms of flow stress versus temperature for constant strain values. From these, together with the original curves, curves were computed showing log strain rate versus inverse temperature, and from these in turn heat of activation was calculated.

Equation . . .

A heat of activation of about 35,000 cal. per mol was associated with the low flow stresses resulting from high temperatures and low strain rates, and this value is the same as for the activation energy for self-diffusion, high-temperature creep, and grain-boundary shearing in the same high-purity aluminum. The authors conclude that the mechanism of plastic deformation in the low stress-strain curves is controlled by a "dislocation climb" process.

The activation energies for the higher stress-strain curves were lower, decreasing from 35,000 to 8700 cal. per mol, as lnZ increased from 29 to 34 per hr. In terms of low stress (at a strain of 0.15 for example), the low stress-strain curves correspond to flow stresses up to 1000 psi., while the high stress-strain curves correspond to flow stresses of 1000 to 12,000 psi. The authors suggest that the lower values of activation energy for plastic flow for the higher stress-strain curves arise from the greater amount of energy supplied mechanically, in turn due to the lesser energy required by thermal fluctuations.

R. I. JAFFEE

Transformation of U-Mo Alloys

Digest of "Transformation Kinetics of Uranium-Molybdenum Alloys", by R. J. Van Thyne and D. J. McPherson. ⊕ Preprint No. 20, 1956.

THE TIME-TEMPERATURE relationships for the eutectoidal decomposition of the high-temperature gamma phase in uranium alloys containing up to 12% molybdenum were determined by isothermal transformation studies. Metallography, X-ray diffraction, electrical resistivity and hardness measurements were used to detect phase changes.

Samples containing 5.4, 8, 10 and 12% molybdenum were prepared by arc melting or by arc melting and vacuum casting. The protected specimens were annealed at 1832° F. and quenched into lead or lead-tin baths held at the transformation temperatures (390 to 1060° F.).

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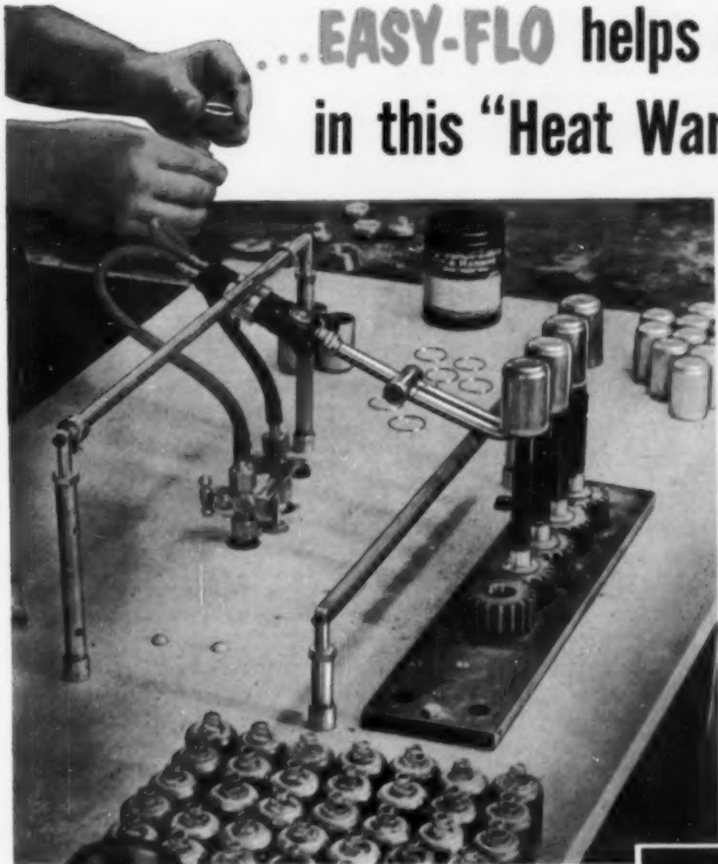

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U-Mo Alloys . . .

body-centered cubic gamma phase decomposes into orthorhombic alpha-uranium and epsilon phase, an ordered body-centered tetragonal phase containing about 15.5% molybdenum. The eutectoid point is located at about 1070° F. and 11.5% molybdenum. This study indicates that the nose of the TTT-curve for the 5.4% Mo alloy is at 1020° F. and 0.1 hr. Transformation of the gamma phase begins in about 2 hr. at 750° F. and 100 hr. at 570° F. No decomposition was observed after 700 hr. at 390° F.

Longer times are required for the initiation of transformation in alloys with more than 5.4% molybdenum. The gamma phase in the alloy containing 12% Mo did not decompose after even 1000 hr. at 660° F.

The observed time for initiation of transformation depends on the method of measurement. Metallography is best for the detection of incipient transformation in the 5.4% Mo alloy and measurement of electrical resistance is best for alloys with higher molybdenum content. X-ray diffraction is not satisfactory for determining when decomposition begins but is the best method of identifying decomposition products. The usefulness of hardness measurements is somewhat limited by pre-precipitation hardening.

R. F. Stoops

Oxidation Resistance of Cr-Ni-Fe Alloys

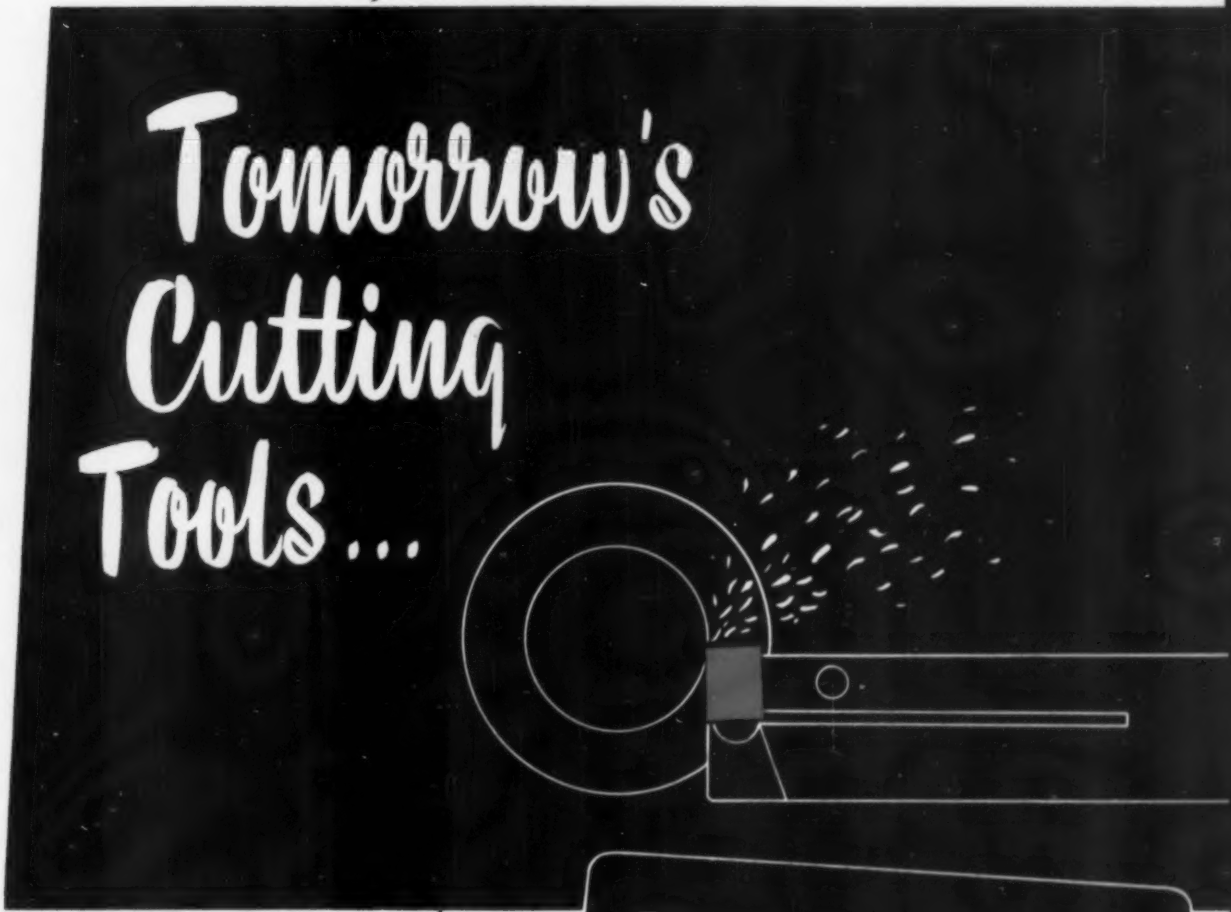
Digest of "Some High-Temperature Oxidation Characteristics of Nickel With Chromium Additions", by G. E. Zima. Preprint No. 37, 1956.

Although nickel-chromium alloys containing 16 to 20% Cr are among the most important bases for oxidation resistant alloys, there is surprisingly little information on the factors responsible for their low scaling rates.

Their oxidation behavior is complicated, with the oxidation rate of relatively low-chromium alloys being increased to a maximum before decreasing to the low values as the chromium reaches 20%. This paper attempts to clarify the effects of chromium on the NiO scale, which is of the metal-deficit p-type semiconducting class.

The alloys investigated contained 0.32 to 15% Cr by weight. (Supplemental data on a 20% alloy was supplied by E. A. Gulbransen of Westinghouse Research Laboratory.) The alloys were rolled to 0.020-in. strip and annealed at 2300° F. for 24 hr. to a large grain size. Oxidation tests were mostly at 2000° F. The alloys with up to 7.6% Cr oxidized according to the parabolic rate law, $W^2=K_pt$, where W is the weight gain in g. per cc. and t is the time in seconds. Alloys with 8.7, 11.1, and 14.9% chromium were assumed to do the same and their K_p constants were averaged from multiple 6-hr. exposures at 2000° F. Gulbransen found that the 20% alloy also had a parabolic scaling curve at this same temperature. The ratio of scaling rates of the nickel-chromium alloys to pure nickel increased from 1 to 12.4 at 7.6% Cr, dropped sharply to 0.69 at 11.1% Cr, and then more gradually to 0.013 at 20% Cr.

The scales consisted of an outer massive green-black layer of NiO containing more and more dispersed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Cr-Ni-Fe Alloys . . .

Cr_2O_3 crystals as the chromium content increased, and a powdery substrate under this scale whose amount also increased with chromium. During cooling, the outer layer of NiO separated from the substrate to a greater extent as the chromium content increased. The substrate was found to consist of NiO, Cr_2O_3, and a spinel ($NiCr_2O_4$). The concentration of the spinel increased to a maximum at 8.7% Cr (approximately the content of maximum oxidation rate) and decreased to practically nothing at 14.9% Cr. The concentration of Cr_2O_3 increased progressively as the chromium content increased; at the metal interface, the substrate was believed to consist entirely of a layer of Cr_2O_3. The coincidence of the highest oxidation rate with the peak content of spinel, and the lowest oxidation rate with increasing Cr_2O_3, is significant.

In analyzing the substrate after deep scribing, some metal lines corresponding to substantially unalloyed nickel were found. This would suggest that Cr_2O_3 enters the oxide by reduction of NiO by chromium.

The lattice constant of the NiO in the scale decreases to a minimum at 2% Cr, as the lattice becomes saturated with chromium. However, for thin samples that were totally oxidized, the minimum in the NiO lattice constant and the apparent chromium solubility occurred at about 4% Cr in the oxide. This suggests that the conditions existing in the scale depart considerably from equilibrium. Beyond 2% Cr, the lattice constant of NiO increases, apparently because of interstitial solution of one or more of the ions involved.

According to the oxidation theory based on the defect model, it was expected that the initially decreased oxidation resistance would correspond to an increased number of nickel ion vacancies until the chromium was saturated. This was not found to be true. In general, the experimental results were much more complicted than could be explained by simple models based on defects in the NiO lattice or mixed Ni-Cr oxide lattices. The authors conclude that the Cr_2O_3 rather than the spinel imparts oxidation resistance to the Ni-Cr alloys.

R. I. JAFFEE

Work Hardening High-Manganese Steel

Digest of "Transformation Products in Cold-Worked Austenitic Manganese Steel", by R. K. Buhr, S. L. Gertsman and J. Reekie. ⊕ Preprint No. 28, 1956.

MANY THEORIES have been proposed to explain the marked increase in hardness of austenitic manganese steel obtained by cold working. Early investigators thought that part of the austenite transformed to martensite and that the transformation occurred in the slip planes produced by cold working the steel. Since the presence of transformation products in the strained steel could not be detected, an alternate theory suggests that the increase in hardness is the result of grain fragmentation and interlocking and blocking effects along the slip planes within austenitic grains.

Samples were prepared from two heats of steel having compositions of 1.25% C, 14% Mn and 1% Si. They were cold worked by dropping a steel weight from various heights so that the weight struck a conical portion of the specimen. A range of impacts from 10 to 150 ft-lb. was used.

The manganese steel was paramagnetic, or very nearly so, when in the unworked condition at 77° F. The value for susceptibility was high, about 28×10^{-6} electromagnetic units per g. After impact, each specimen was mounted in a susceptibility balance and the force exerted on it was measured for a number of field strengths at 77° F. The temperature variation of magnetization was investigated by mounting a small tubular furnace around the specimen between the poles of the electromagnet.

Cold working produces a ferromagnetic component. In a constant field, the amount of magnetization increases with increasing amounts of cold work until a maximum value is reached after which it decreases slightly. Estimates were made of the approximate amount of ferromagnetic constituent and although the values are two or three times those indicated by data plots, it is clear that the amount involved is very small and that in this respect, the transformation differs markedly from that in austenitic stainless steels.

An attempt was made to measure

Work Hardening . . .

the magnetization as a function of temperature and thus determine the nature of the ferromagnetic constituent for several cold worked samples. The results indicate that two ferromagnetic components may be involved, one with a Curie point near 250 to 300° F. and the other having a much higher Curie point. The former may be a complex carbide of manganese and iron and the latter may be alpha iron. Heating to 500° F., even for 20 min., causes a stable increase in magnetization.

The lower impact loads do not work harden the specimens throughout and the maximum hardness occurs at a point below the surface of the cold worked specimens. A rough correlation was found to exist between the "average hardness" and the amount of ferromagnetic constituent produced.

Direct visual evidence was obtained of the existence of a ferromagnetic constituent produced by cold work by using a magnetic colloid technique. A replica electron micrograph of a severely cold worked sample shows sets of parallel lines resulting from severe etch attack along regions of slip bands. They are believed to be due to the formation of a fast-etching secondary phase along slip planes by the cold working strains. These characteristic sets of lines are not present in replicas of unworked specimens.

In summary, when austenitic manganese steel is cold worked by impact, a small quantity, probably not exceeding a few hundredths of a percent, of a ferromagnetic phase is formed. This phase is probably composed of two constituents, a complex carbide and alpha iron. The transformation product appears to be tempered martensite. Some correlation exists between hardness and the amount of ferromagnetic phase present in the cold worked steel. Magnetic colloid tests show the ferromagnetic constituents to be present along the traces of slip planes and along grain boundaries. The hardening mechanism may be similar to that which occurs in age hardening alloys.

G. A. Fritzlen

Evaluating Ultra High-Strength Steels

Digest of "Bend: Tensile Relationships For Tool Steels at High Strength Levels", by J. C. Hamaker, Jr., V. C. Strang and G. A. Roberts. Preprint No. 25, 1956.

In evaluating the mechanical properties of ultra high-strength steels, hardness levels are reached where the bend test seems to offer more reliable and sensitive measurement of strength than the ordinary tensile test. Tensile test results may be erratic because slight misalignment of the specimen holders or small imperfections of the specimen surface can cause brittle failure at or below the yield point, thereby obviating any measurement of the tensile strength or relative ductility. Even when a complete load-extension curve is obtained, the small total deformation is not amenable to accurate measurment and the data show considerable scatter.

High-Strength Steel . . .

The bend test has become a popular method of testing in recent years because specimens are relatively easy to prepare and the stress-strain characteristics can be determined readily with strain gages.

Two medium-alloy toolsteels, heat treated to various hardnesses, were tested in tension and in bending (single and double point loading) to obtain preliminary conversion relationships between the two test methods. In the hardness range from C-30 to 55, tensile strength was equivalent to 45 to 50% of bend strength and the 0.2% offset yield strength was equal to about 88% of bend yield strength. The relationship between tensile elongation and bend deflection is also shown.

The strength of three other toolsteels as a function of hardness was also determined to indicate the general utility of the bend test for evaluation of ultra high-strength materials. An interesting decrease in modulus of elasticity with increasing hardness was observed in three of the alloys.

H. J. ELMENDORF

Transformation of Uranium-Base Alloys

Digest of "Transformation Kinetics of Uranium-Niobium and Ternary Uranium-Molybdenum-Base Alloys", by R. J. Van Thyne and D. J. McPherson. Preprint No. 19, 1956.

THE EFFECT of additions of columbium alone and in combination with molybdenum on the stability of the high-temperature gamma phase in uranium-base alloys was evaluated by determination of TTT-curves. Phase transformation was measured by metallographic examination, X-ray diffraction, hardness and electrical resistance.

Samples were prepared by arc melting or by arc melting and casting. The binary alloys were solution treated at 1920° F. and the ternary alloys at 1830° F. and quenched to the isothermal transformation temperatures.

The gamma phase in the 10 and 20% columbium alloys decomposes into orthorhombic alpha-uranium and another gamma phase containing about 60% Cb. Metallographic exam-

Uranium Alloys . . .

ination indicates that the eutectoid temperature is between 1110 and 1200° F. The nose of the TTT-curve for the 10% Cb alloy is at about 1020° F. and 0.2 hr. Longer times are required for the 20% Cb alloy and the nose of its TTT-curve is at about 1020° F. and 10 hr.

The gamma phase in the ternary alloys decomposes into alpha-uranium and body-centered tetragonal epsilon phase. At 930° F., the gamma phase begins to transform in less time in the 8 Mo, 3 Cb alloy than in the 8 Mo, 1.5 Cb alloy. The stability of the gamma phase is apparently reduced by an increase in the columbium content. At temperatures below 750° F., the situation is reversed and the alloy with 3% columbium is the more stable.

The nose of the TTT-curve for an 8 Mo, 1 Pt alloy is at about 840° F. and 25 hr. After 1000 hr. of annealing at 930° F., this alloy is completely transformed. At lower temperatures transformation is not complete in any of the alloys after exposure up to 1000 hr.

The high-temperature gamma phase in uranium-base alloys is stabilized by the alloying elements tested. Extrapolation of the TTT-curves of the three ternary alloys indicates that the gamma phase in the 8 Mo, 3 Cb alloy is more stable at temperatures below 660° F. than gamma phase in the other two alloys.

R. F. Stoops

Effect of Sulphur in Titanium Alloys

Digest of "The Effect of Sulphur on the Properties of Titanium and Titanium Alloys", by L. W. Berger, D. N. Williams and R. I. Jaffee. ⊕ Preprint No. 12, 1956.

Sulphur additions to commercially pure titanium have been found to increase the tensile strength at concentrations up to 0.68% and cause a corresponding decline in ductility. This paper reports the effects of sulphur in both sponge-base and iodide-base binary titanium-sulphur alloys and the effects of minor amounts of sulphur in various commercial and

(Continued on p. 228)

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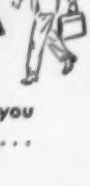

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We'd like to show our vertical tube vertically. Do you mind turning the magazine?

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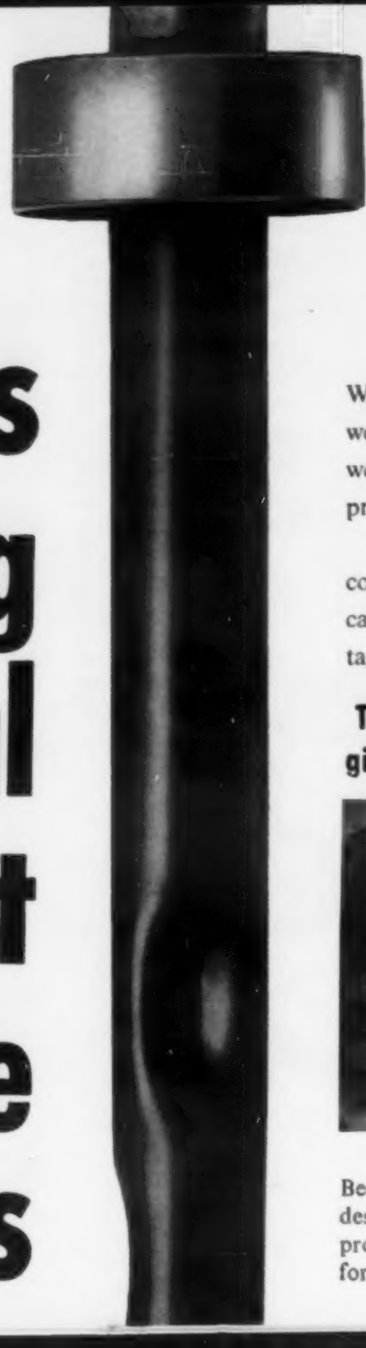


A better way to apply heat to metal

When metal needs heat, Lindberg furnaces with the new Lindberg lightweight vertical radiant tube offer a better way to apply it. Industry the world over is finding that Lindberg furnaces with this new vertical tube provide advantages no other type of furnace can give.

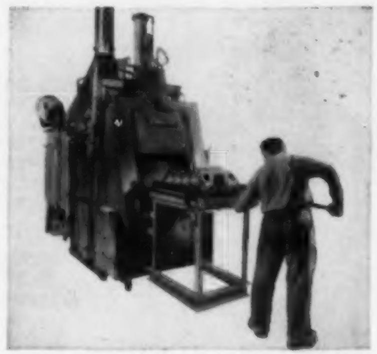
Whatever type or size of furnace fits your production needs, from gigantic continuous pusher-type to the small batch-type furnace, Lindberg engineers can develop exactly the right equipment for you, embodying all the advantages of this revolutionary new vertical radiant tube.

The Lindberg vertical tube gives you these advantages

Improved Performance

Because of Lindberg's revolutionary design, this tube (patent applied for) provides a new level of furnace performance. The secret lies in the new

Typical Lindberg Vertical Tube Furnaces



Lindberg gas-fired vertical radiant tube carburizing and carbonitriding furnace. The Lindberg vertical tube is ideal for these heat treating processes which require rapid uniform heating.

furnace efficiency and lowers costs

This scale reproduction is exactly one-fourth actual size.

Lindberg tube's "dimples." Here's how they work—in the radiant tube a central stream of mixed air-and-gas is surrounded by a cylindrical stream of air alone and combustion occurs in the area between these two streams. The "dimples" create eddies in the streams accelerating combustion and maintaining even temperatures along the entire tube.

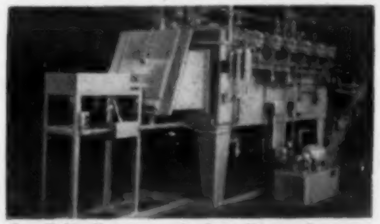
Maximum Dependability

This Lindberg tube will operate at maximum efficiency for a longer period of time. The special green silicone enamel, a Lindberg exclusive, gives greatest possible resistance to carbon penetration and greatly prolongs tube's operational life. Vertical position eliminates soot deposit inherent in horizontal tubes with resultant temperature increases at points of sooting. Lindberg tubes work effectively longer.

New Economy In Operation

With Lindberg vertical radiant tubes the bulk and bend problems of old-fashioned horizontal tubes are eliminated. Tubes are just 59 inches long and weigh only 29 pounds. No costly furnace shut-downs and no high labor and material cost for tube change. Turn off the furnace, lift out the old tube, put in the new one. Literally, a matter of minutes. Savings in space and fuel costs, too.

Lindberg vertical radiant tube pit carburizing furnace. Note small amount of space required for tubes.



Small Lindberg vertical radiant tube gas-fired hydraulic pusher type carburizing furnace. In this installation heating chamber is only 10 inches high.

Lindberg Radiant Tube Batch Type Box Furnace. Even small furnaces can be heated efficiently with radiant tubes.

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Sulphur in Ti . . .

experimental alloys. Additions up to 18.5% sulphur were studied.

The room-temperature solubility of sulphur in titanium appears to be between 0.009 and 0.017%. Since an initial sharp increase in strength occurs before sulphides are evident in the microstructures of specimens, the considerable strengthening of titanium observed with a corresponding sharp decline in ductility probably results from solid-solution hardening.

Additions up to 0.025% cause significant increases in tensile and yield strengths. Sulphur up to 0.45% caused only a slight increase in strength and a decline in ductility.

As little as 0.004% sulphur refines the grain size of both as-cast and wrought titanium. The maximum effect is obtained with about 0.05% sulphur. Sulphide networks are formed in castings containing as little as 0.25% sulphur and they act as grain refiners. The networks may be broken up by subsequent working and annealing treatments. Annealing for long times in the alpha field causes considerable grain growth in the sulphide-containing alloys. Sulphur additions have little effect on the beta transus of titanium.

Additions of 0.2% sulphur to titanium alloys containing molybdenum, vanadium or aluminum plus vanadium cause a marked increase in yield strength with only a slight decline in ductility. This amount of sulphur is sufficient to refine the grain, both as-cast and wrought.

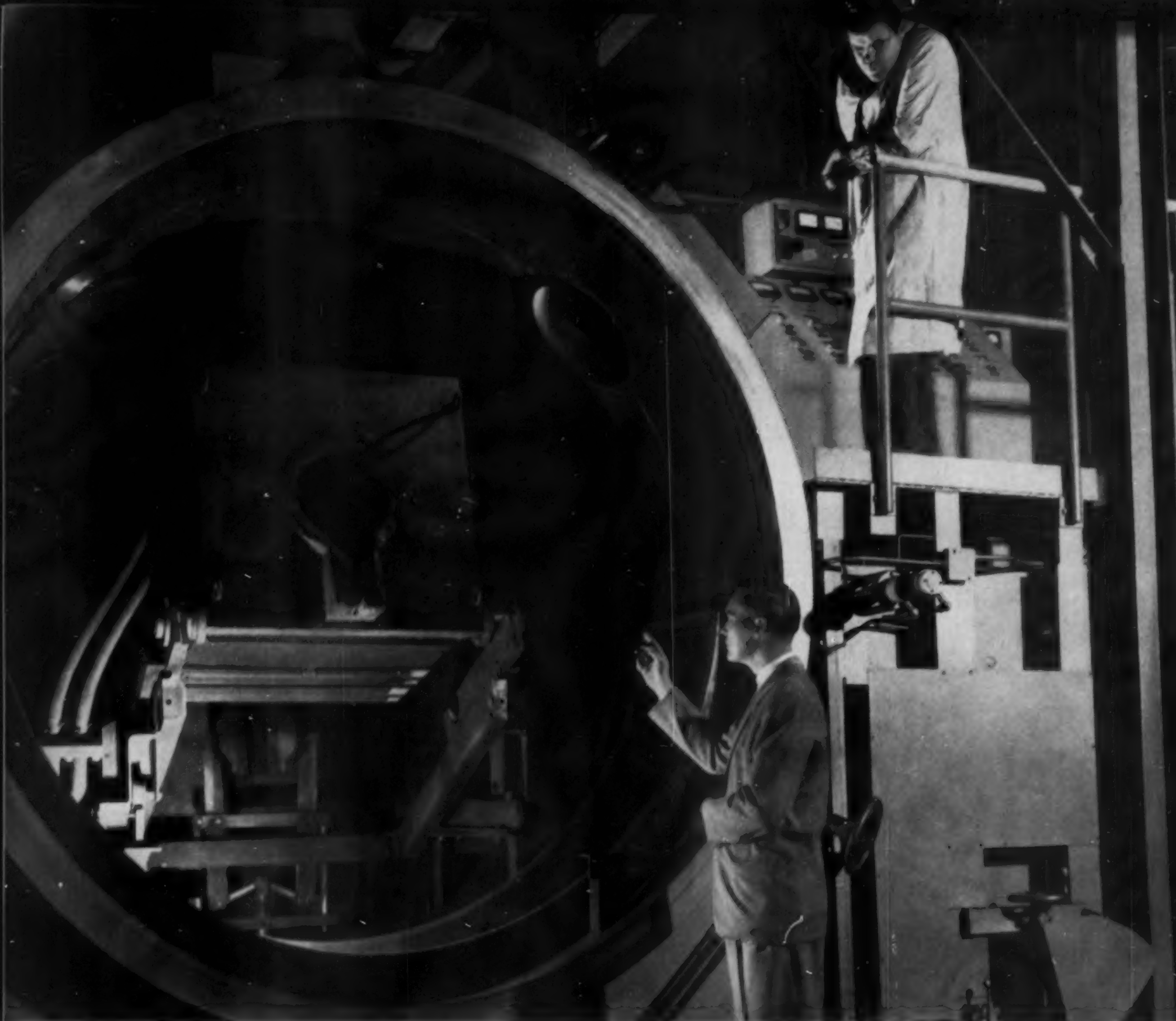
G. A. Fritzlen

Complex Carbides in Cr-Co-Mo-Ti-Fe Alloys

Digest of "Influence of Molybdenum on the Phase Relationships of a High-Temperature Alloy", by H. J. Beattie, Jr., and F. L. VerSnyder. Preprint No. 35, 1956.

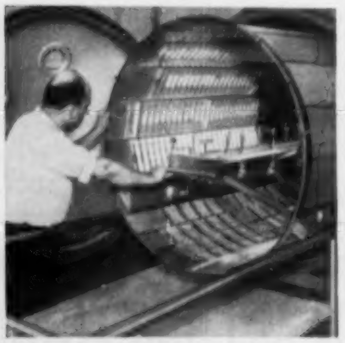
A number of nickel-base alloys include molybdenum as an alloying element to impart strength at high temperature. Most of these alloys have one or more disperse carbide phases of the types $M_{23}C_6$ and M_6C, in both of which part of the

(Continued on p. 232)



Incorporated within vacuum chamber is a rail-mounted ingot mold carriage, which passes through the vacuum lock, moves into position to receive the heat of processed metal and then carries it out on to the mold storage floor. Vertically-hinged door swings fully open, permitting unobstructed access to interior of furnace.

The metals industry is profiting from the use of other STOKES production equipment



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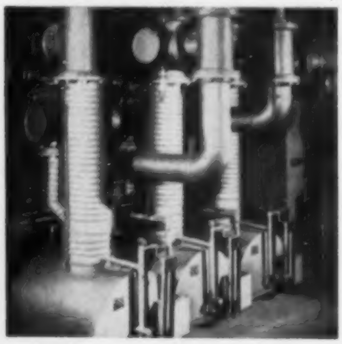

Vacuum Pumps. For rapid evacuation and holding high vacuums, Stokes offers mechanical pumps, and "Ring-Jet" oil vapor diffusion and booster pumps. New design affords 10 to 100% greater speeds.

Stokes vacuum furnace installed by Allegheny Ludlum for high alloy steel melting

Research studies with new unit will precede production operations on semi-continuous basis

THIS new Stokes high-vacuum furnace was recently installed at the Watervliet, N. Y. plant of Allegheny Ludlum Steel Corporation. It is an important component of the company's new Induction Vacuum Department . . . which, for the immediate future, will devote itself to various aspects of a development program on a wide variety of alloy steels.

Featuring a particularly compact and simplified design . . . the unit permits the direct flow of materials through the chamber, eliminates the need for costly auxiliary equipment, and minimizes the space required for operations. Controls for vacuum pumping, charging, alloying, melting, and casting are centralized and conveniently located.

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Reference Data:

Microvac Pumps—Catalog 750
Diffusion and Booster Pumps
Specification and Performance Data
Story of the Ring-Jet Pump
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STOKES

Complex Carbides . . .

metal atoms are known to be molybdenum. Its effects on the carbide phases and phase relationships have now been studied in some nickel-base alloys containing 0.1 to 0.2% carbon, 16 to 22% chromium, 10% cobalt, 2 to 3% titanium, 2 to 3% iron, and small quantities of aluminum, manganese, silicon and nitrogen. Molybdenum additions ranged from 2 to 11%.

All alloys were solution heat treated, then aged in the range 1200 to 1800° F. for 50 to 1000 hr. Examinations included electron diffraction and X-ray. Carbide particles were delineated by selective etching, and sometimes recovered for further study by dissolving the matrix.

The action of titanium was of much interest. As the quantity of M_6C precipitate increased, the matrix solubility for titanium increased and the TiC disappeared. Titanium therefore does not suppress formation of complex carbides in these alloys. Types $M_{23}C_6$ and M_6C may precipitate simultaneously and coexist, however.

Two types of precipitates were formed, namely, a disperse second phase, and a "cellular" precipitate largely at grain boundaries. The latter occurred at lower temperatures and after shorter aging times and seemed to be associated with the complex carbide, $M_{23}C_6$, only.

Stability of $M_{23}C_6$ is dependent on the amount of molybdenum present. The "cellular" $M_{23}C_6$ was stable in alloys containing up to 6% molybdenum; higher contents promoted the preferential formation of M_6C.

Lattice parameters of both the complex carbides increase with increasing molybdenum in the alloy. Two different M_6C carbides are reported in the alloys containing 8.5 and 11% molybdenum; only one of these has an expanding lattice. The phase with constant lattice size was relatively tightly packed: 10.85 Angstrom units. Duality of the M_6C carbide phase was also observed in alloys and after heat treatments that also produced sigma phase and a distinct break in the lattice parameter of the matrix metal. These facts are considered to be interrelated and may be a key to a better understanding of sigma phase formation.

J. L. Wyatt

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Ti and B in Heat Resistant Steels

Digest of "High-Temperature Rupture-Strength Properties of Chromium-Nickel Stainless Steels Containing Titanium and Boron", by J. Salvaggi and L. A. Yerkovich. ⊕ Preprint No. 33, 1956.

STRENGTHENING of leaner alloys for aircraft construction was the purpose of this research. Using stainless steels of Type 302 (18-8 Cr-Ni) and Type 316 (17-12-2.5 Cr-Ni-Mo), some 130 melts with 0.07 to 0.30% C were surveyed to define the effects of 0.15 to 1.50% Ti, 0.05 to 0.75% B, and their combinations on stress-rupture properties of hot rolled 0.050-in. sheet. Solution treatments at 2100, 2200 and 2300° F. were included, the higher temperatures being markedly beneficial when incipient fusion was avoided. Limiting rupture stress (LRS) for 100-hr. life at 1500 and 1350° F. was the criterion.

With 0.75% Ti and 0.15% C in 18-8, the maximum LRS at 1500° F. was 14,800 psi. This appears much superior to the 5000 to 6000 psi. expected from commercial Type 321 stainless, and may be due in considerable part to the solution treatment at 2300° F. Aging 100 hr. at 1350 or 1500° F. increases hardness from Rockwell B-75 to about B-88.

Boron at 0.40% (with 0.15% C) attained a maximum LRS of nearly 20,000 psi. at 1350° F. and 10,000 psi. at 1500° F., along with a threefold increase in hot ductility (after a 2100° F. solution treatment). Precipitation hardening probably is a contributing factor, as aging for 100 hr. increased hardness from B-80 to about B-112, and a boride constituent appeared in the microstructure. Since boron encourages eutectic formation and lower melting points, its optimum use requires lower solution temperatures.

Titanium and boron together were beneficial after treating at 2100° F., with a peak LRS and high ductility at 1500° F. of 11,800 psi., compared to 10,000 psi. when boron or titanium was added alone. Optimum combinations were 0.07% C, 0.15% B, 0.15% Ti, and 0.15% C, 0.50% B, 0.15% Ti, with peaks occurring at progressively lower titanium contents as boron was increased.

Molybdenum-bearing Type 316 stainless sheet has an LRS expectancy of around 9000 psi. at 1500° F. This was boosted to about 18,500 psi. by 0.8% Ti and a 2300° F. treatment; 5% ductility implies a marked increase in creep resistance.

Boron in the 17-12-2.5 Cr-Ni-Mo base also increased LRS values at 1500° F. to 16,000 psi. with 0.15% C plus 0.15% B, and 18,000 psi. at 0.30% C plus 0.85% B (using a 2200° F. treatment). Again, hot ductility was increased after a solution treatment at 2100° F.: 55% with 0.07% C plus 0.27% B compared with 5.5% without boron. Solution temperatures above 2200° F. were undesirable, for a eutectic formed which interfered with hot rolling qualities.

Combinations of titanium and boron, with 2100° F. solution treatment, gave better results than these elements separately in the Type 316 base, and without loss of ductility. The peak was 15,700 psi. at 0.15% C, 0.50% B and 0.13% Ti. With 2300° F. treatment the peak was 20,600 psi., but ductility was only 2%. The com-

Heat Resistant Steels . . .

position seemed to promote grain refinement; 1500° F. exposure developed fine precipitates which were better dispersed than in the Type 316 alloy, where they tended to follow grain boundaries. Boron appeared to encourage a peppery precipitate and after 2200° F. a eutectic was evident.

The unalloyed Type 316 base showed some evidence of intergranular oxidation after heating in air at 2300° F. In contrast, the Type 316 with 0.81% Ti retained a stable microstructure after solution treatment at 2300° F. and had an LRS of 18,500 psi. at 1500° F.

These benefits appear to be significant and an encouraging step in the search for leaner aircraft alloys.

H. S. Avery

Precipitation Hardening of Cr-Mn Stainless Steels

Digest of "Precipitation Reactions in Austenitic Cr-Mn-C-N Stainless Steels", by Chi-Mei Hsaio and E. J. Dulis. Ⓐ Preprint No. 26, 1956.

Two types of precipitation reactions occur during heat treatment of austenitic chromium-manganese-carbon-nitrogen steels. The first is characterized by the formation of lamellar nodules at grain boundaries. The second is a general precipitation which results in a structure of the Widmanstätten type.

Three steels were studied containing 13 to 17% manganese, 18 to 23% chromium, 0.40 to 0.43% carbon and 0.14 to 0.17% nitrogen. Samples were prepared from 15-lb. induction-melted heats by forging to ⅝-in. square bars. All were solution annealed at 2200° F. for 30 min. and water quenched. The aging treatments consisted of heating at temperatures between 1000 and 2000° F. for various times and water quenching. Some samples were quenched directly from the solution annealing temperature into lead baths at aging temperatures, held for various periods of time and water quenched.

Magnetic susceptibility measurements were used to establish austenite stability after heat treatment. Microstructures of the heat treated

Cr-Mn Stainless . . .

steels were studied and lineal analyses were made to determine the kinetics of the grain boundary reaction. X-ray diffraction measurements of both electrolytically extracted residues and solid samples were used to identify the precipitated phases.

It was concluded that the formation of lamellar nodules at grain boundaries is predominant at aging temperatures above 1500° F. On the other hand, this reaction is retarded at aging temperatures below 1500° F. and general precipitation is predominant. Slow cooling from the solution annealing temperature promotes the grain boundary type of precipitation.

The authors established that the grain boundary reaction is a nucleation and growth process. Thermodynamic treatment of the aging curves for this reaction indicates that the activation energy is 57 kg-cal. per g-mol. in initial stages and 68 kg-cal. per g-mol. in the later stages.

All steels were nonmagnetic after heat treatment which indicates that neither austenite decomposition to ferrite nor austenite transformation to martensite occurred. The X-ray diffraction work revealed that lamellar nodules in the grain boundaries consisted of austenite and $M_{23}C_6$ carbide. The lattice constant of the austenite in the nodules was somewhat smaller (3.615Å) than that of unaged austenite (3.652Å). The composition of the carbide in the lamellar nodules was determined to be $(Cr_{17}Fe_4Mn_2)$ $(C_{5.7}N_{0.3})$ when chemical analyses were compared with the distribution of alloying elements between the matrix and the precipitate.

Both types of precipitation reaction increased the hardness of the steels studied. General precipitation of the Widmanstätten type increased hardness more than grain boundary precipitation.

S. T. Ross

Tensile Properties of Metals at Low Temperatures

Digest of "Some Exploratory Observations of the Tensile Properties of Metals at Very Low Temperatures", by E. T. Wessel, Preprint No. 3, 1956.

LOW-TEMPERATURE RESEARCH is making important contributions to a better understanding of the flow and fracture properties of metals. A considerable amount of information has been developed recently in connection with low-temperature embrittlement. Certain generalizations concerning the relationships between this phenomenon and crystal structure have been made. The present research covered tensile tests of metals having various lattice structures at temperatures ranging down to −452° F. Such tests have been made possible by the recent development of an automatically controlled refrigerating system employing liquid helium.

Annealed commercially pure nickel (face-centered cubic) tested over the range 1110 to −452° F. showed a gradual increase in yield strength

Tensile Properties . . .

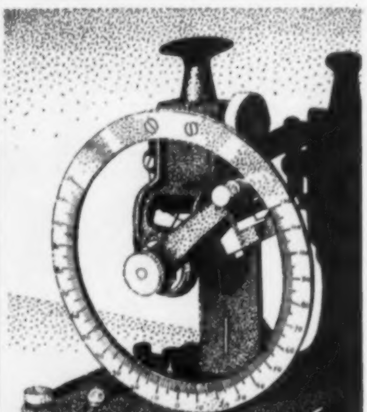
with decreasing temperature, the value at the lowest testing temperature being about double that at the highest temperature. A five-fold increase in the tensile strength occurred over the same temperature range. Uniform elongations of the nickel specimens were highest at the lowest testing temperature. The ductility remained high throughout the temperature range but dropped somewhat in the range –330 to 80° F., possibly as a result of precipitation of impurity elements.

Tensile properties of close-packed-hexagonal zirconium were affected by temperature change in about the same manner as those of nickel. The ductility was lower in the range –330 to 32° F., than at either lower or higher temperatures, an effect attributed to strain aging.

In contrast to nickel and zirconium, body-centered cubic beta brass showed a strong dependence of yield strength on temperature with an approximate seven-fold increase from room temperature to –452° F. Despite this precipitous rise in the yield strength, the brass exhibited relatively high ductility (20% uniform elongation) even at the lowest temperature.

The yield strength of quenched and tempered S.A.E. 4340 steel increased about 65% over the range from room temperature to –452° F. and the ductility decreased gradually, showing no sharp transition from ductile to brittle behavior.

(Continued on p. 242)



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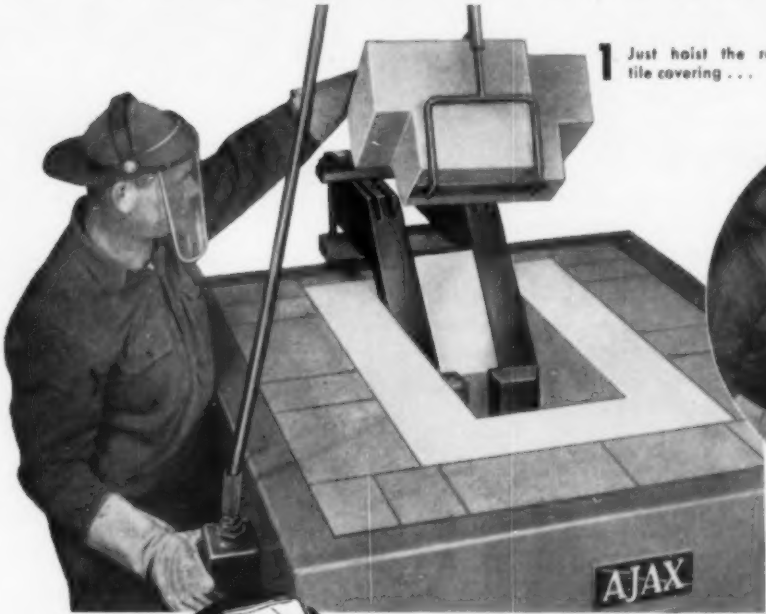

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Tensile Properties . . .

The value of reduction in area for quenched and tempered S.A.E. 3335 also decreases gradually with temperature but drops sharply at -300° F. However, even at -452° F. its reduction in area was 42%.

Despite the strong temperature dependence exhibited by the yield strengths of the body-centered cubic metals, the experimental results obtained at the lower temperatures failed to conform with either the Zener-Hollomon or Cottrell-Bilby flow stress temperature relationships which predict even greater yield strength increases than those observed. The yield strength behavior of the alloy steels tested was considered to represent the composite effects of two components; one was relatively independent of temperature and was accounted for by the dispersion of carbide particles and the other was associated with alloyed ferrite and was strongly temperature dependent.

H. Y. Hunsicker

Growth of Uranium During Thermal Cycling

Digest of "The Plastic Deformation of Uranium on Thermal Cycling", by H. H. Chiswik. Preprint No. 21, 1956.

This interesting study covers the interrelationships between the growth of uranium during thermal cycling and its grain size and orientation. The raw material for samples was beta-treated pure uranium rod. After suitable conditioning of structure, samples were subjected to thermal cycling between 50 and 550° C. (120 to 1020° F.) using a liquid bath of NaK in a furnace with special zone controls. The cycling conformed to a precise time schedule and was carried to a total of 700 cycles.

The data show that the greater the preferred orientation created by rolling, the greater the growth in thermal cycling when grain size is held constant. A reduction in area of 3% by rolling causes 11% growth in 700 thermal cycles; 74% reduction results in growth of 34%.

A pronounced difference in growth

Growth of Uranium . . .

in samples having a constant level of preferred orientation corresponding to 70% reduction is also created by variation of grain size. The larger grains (0.18 mm.) produce moderate growth (13%) whereas fine grains (0.014 mm.) contribute to marked growth (59%).

Microstructural studies revealed that continued cycling generates subgrains; this suggests that coarse-grained material might be expected to increase in growth with continued cycling because of these new grains. All samples developed internal porosity. This was unrelated to grain size, orientation or the amount of growth created. While no relationship to inclusions or grain boundaries was found, the presence of the pores is believed related to the impurities present. High-purity uranium (100 ppm. maximum impurity content) has been carried to 3000 cycles and 400% elongation without evidence of porosity.

An interesting chart of growth rate plotted against degree of anisotropy suggests that complete achievement of random orientation might eliminate growth from thermal cycling as controlled in these experiments.

J. A. Fellows

Austenite Stability of Fe-Cr-C-N Alloys

Digest of "Phase Relationships and Mechanical Properties of Some Iron-Chromium-Carbon-Nitrogen Alloys", by G. F. Tisinai and C. H. Samans. Ⓐ Preprint No. 30, 1956.

Austenite can be retained at room temperature by cooling properly balanced iron-chromium-carbon-nitrogen alloys rapidly from 2200° F. The austenite decomposes to ferrite plus carbides and nitrides when cooled at slower rates. The effect of lower quenching temperatures on austenite stability of such steels containing 21 to 23% chromium is reported in this paper.

The phase relationships were studied by X-ray diffraction, metallography, hardness testing and magnetic susceptibility measurements. For the X-ray determinations, samples consisted of filings sealed in Vycor tubes

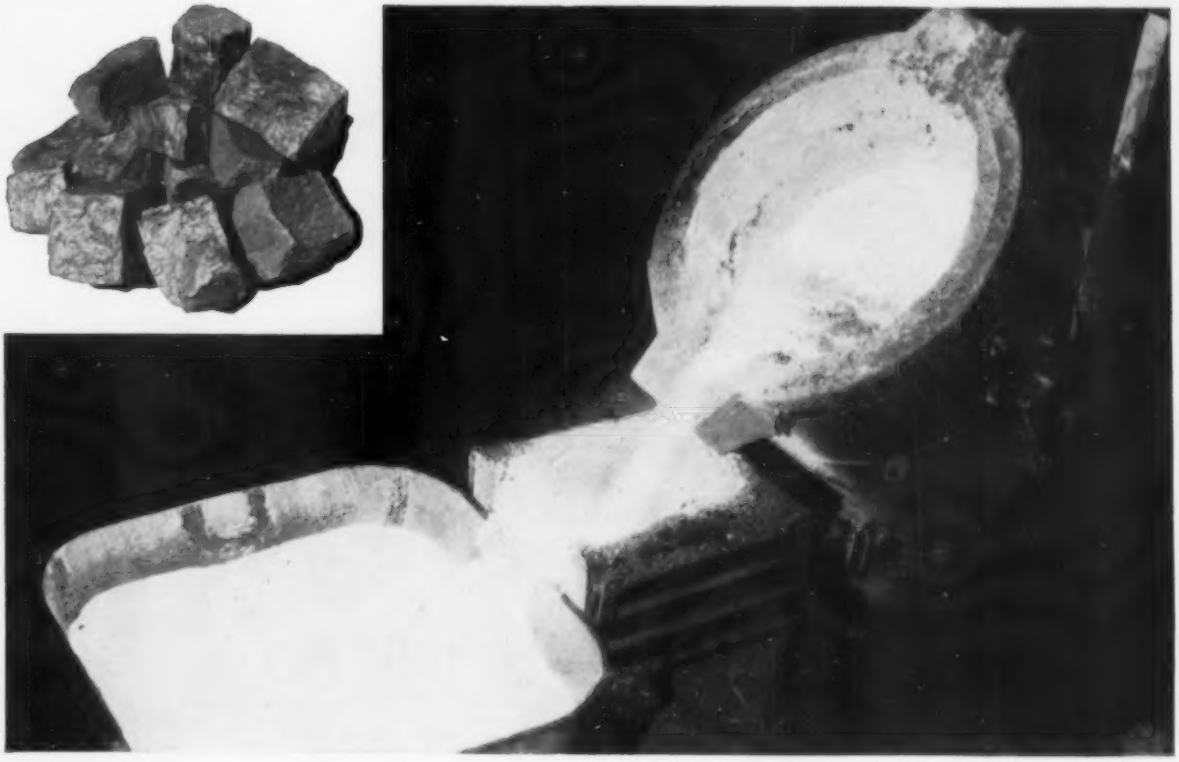
Austenite Stability . . .

and heated at temperatures between 1300 and 2200° F. Solid samples were employed for the other methods of study. All samples were heated for 20 hr. and water quenched.

Metallographic examination was used to detect the following structures: free polygonal ferrite, lamellar ferrite formed in conjunction with carbides and nitrides as a result of austenite decomposition, stable austenite and martensite. X-ray diffraction techniques were employed to detect stable austenite and martensite and to determine the type of carbides

and nitrides present. Hardness data were used to follow the course of the martensite reaction. A Magne-Gage was used to indicate the presence of ferrite.

The martensite reaction was pronounced for all austenite formed below 2000° F. in the 21% chromium alloys. The maximum amount of martensite formation appeared in alloys quenched from 1700 to 1800° F. The martensite reaction was noted in 27% chromium alloys but to a lesser extent. No martensite was found in structures of the 33% chromium alloys. The martensite transformation is inhibited when the austenite of the alloy is sufficiently rich in chromium, nitrogen and carbon. In the 21 and 27% chromium alloys, heat treatment at high temperatures will dissolve sufficient carbon and nitrogen to enrich the austenite enough that martensite cannot form on quenching. (*Continued on p. 252*)



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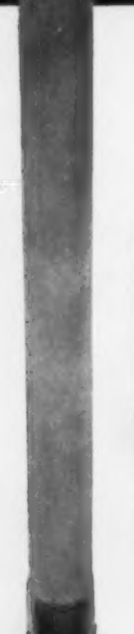

R. W. Cheek
Manager, Induction Heating Department

"Three different axle-hardening applications," reports R. W. Cheek, "show a slice of Westinghouse experience in solving production line heat-treating problems. Dependability of Westinghouse induction equipment, for example, protects production timing and holds maintenance to a minimum. Results are measured, too, in three important profit advantages."

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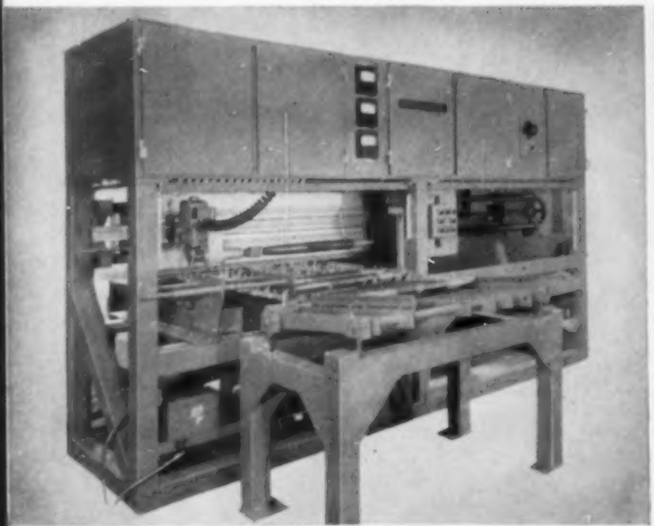
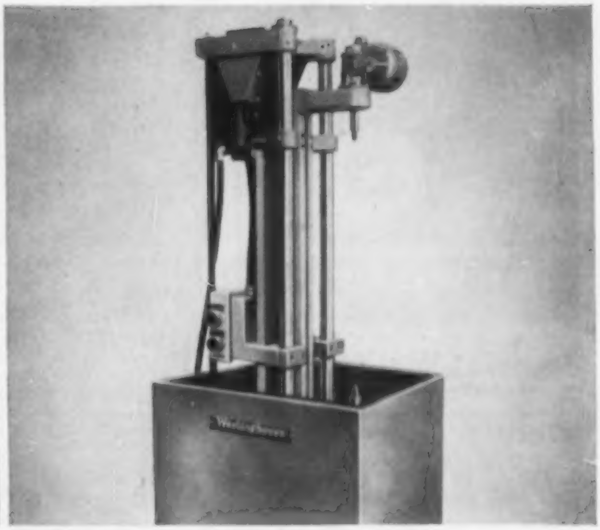
fatigue strength . . . lowers cost



2. As many as 33 axle shafts up to 42 inches long and weighing up to 100 lbs. are surface-hardened by this Westinghouse induction equipment.



3. Westinghouse general-purpose induction scanner handles shafts up to 30 inches long, 80 lbs. weight, for surface-hardening and quenching.

Many other factors, such as savings in floor space, rapid start-up, and cooler more productive working conditions add to the high efficiency of each installation.

A profit return for you? Westinghouse induction-heating experience can show you production problems turned into profitable solutions for hardening, annealing, joining, or forging. Why not call on your local Westinghouse industrial heating sales engineer? He'll bring you expert problem solving and complete service. Westinghouse Electric Corporation, Industrial Heating Division, Meadville, Penna. J-10455

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Austenite Stability . . .

The Fe-Cr-C-N alloys have excellent room-temperature tensile properties when completely austenitic. At intermediate elevated temperatures, alloys containing ferrite, carbides and nitrides have tensile properties comparable to ferritic stainless steels. Tensile properties at 2000° F., where these alloys are completely austenitic, are at least equal to those of austenitic 25 Cr, 20 Ni steels.

S. T. Ross

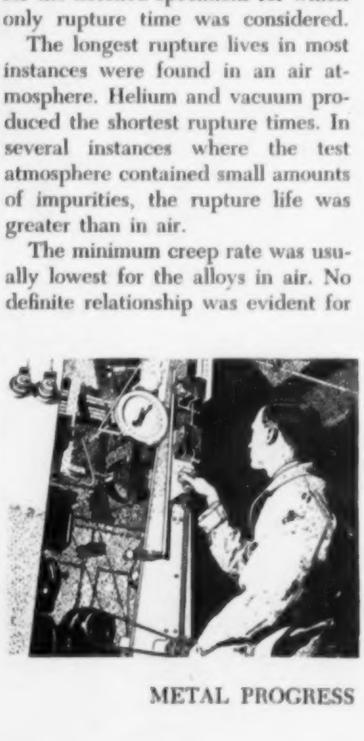
Effect of Environment on Creep-Rupture Properties

Digest of "Effect of Environment on Creep-Rupture Properties of Some Commercial Alloys", by Paul Shahinian. Preprint No. 34, 1956.

The effect of the atmosphere on the creep and rupture properties of a number of high-temperature alloys was investigated. Creep-rupture tests were conducted on both notched and unnotched specimens for times up to 500 hr. at temperatures ranging from 1100 to 1500° F. The effect of the environment on the properties of the alloys was analyzed in terms of rupture time, minimum creep rate, elongation at fracture and reduction in area, except for the notched specimens for which only rupture time was considered.

The longest rupture lives in most instances were found in an air atmosphere. Helium and vacuum produced the shortest rupture times. In several instances where the test atmosphere contained small amounts of impurities, the rupture life was greater than in air.

The minimum creep rate was usually lowest for the alloys in air. No definite relationship was evident for



Creep-Rupture . . .

the effect of the other atmospheres on the minimum creep rate. The ductility was greatest for tests in vacuum.

For the notched specimens it was found that in alloys of relatively low ductility, the notch increased the effects of the environment. Oxidizing atmospheres produced a greater notch strengthening than the inert atmospheres.

The mechanism of the strengthening effect of an oxidizing atmosphere may be attributed to a combination of several factors. Internal oxidation may strengthen the grain boundaries without producing any marked change in over-all hardness of the alloys, thus decreasing the creep rate. In addition, crack propagation may be inhibited by oxidation of the tip of the crack which decreases the effective tip radius. Other possible factors include surface oxide films which may inhibit the generation or migration of dislocations or strengthen the bulk material. The results obtained on the notched specimens support the view that the oxidation of the tip of an advancing crack may be the major factor in explaining the effect of environment on the creep properties. The investigation also shows that the notch sensitivity and environment must be considered together.

W. A. Morgan

Aging Reactions in Superalloys

Digest of "Aging Reactions in Certain Super Alloys", by W. C. Hagel and H. J. Beattie Jr. Preprint No. 40, 1956.

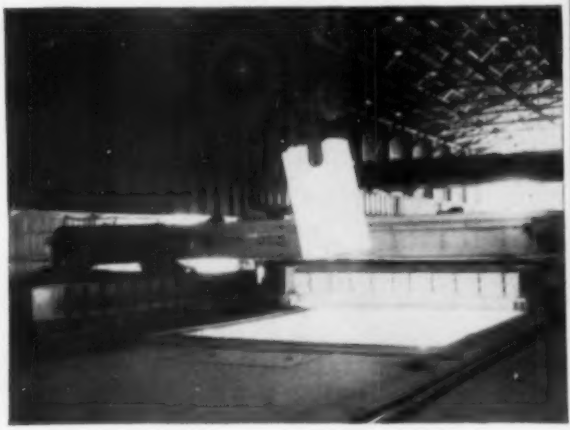
Few systematic studies have been made on the aging reactions in superalloys which precipitation harden by the formation of complex carbides, nitrides and other intermetallic compounds. For this reason the aging process in samples of hot worked and samples of arc-melted, hot worked and homogenized alloys of N-155, G-18 B and 15-15 N was investigated. The changes in properties and structures of the specimens were determined as a function of the solution treatment at 1800 to

(*Continued on p.* 258)

Open Hearth Furnaces—Photo Courtesy
Jones & Laughlin Steel Corp.

Continuous Heating Furnaces—
Photo Courtesy Crucible Steel Co.

Soaking Pit—Photo Courtesy
United States Steel Corp.



Heat Treating Furnace—
Photo Courtesy Taylor Forge & Pipe Works

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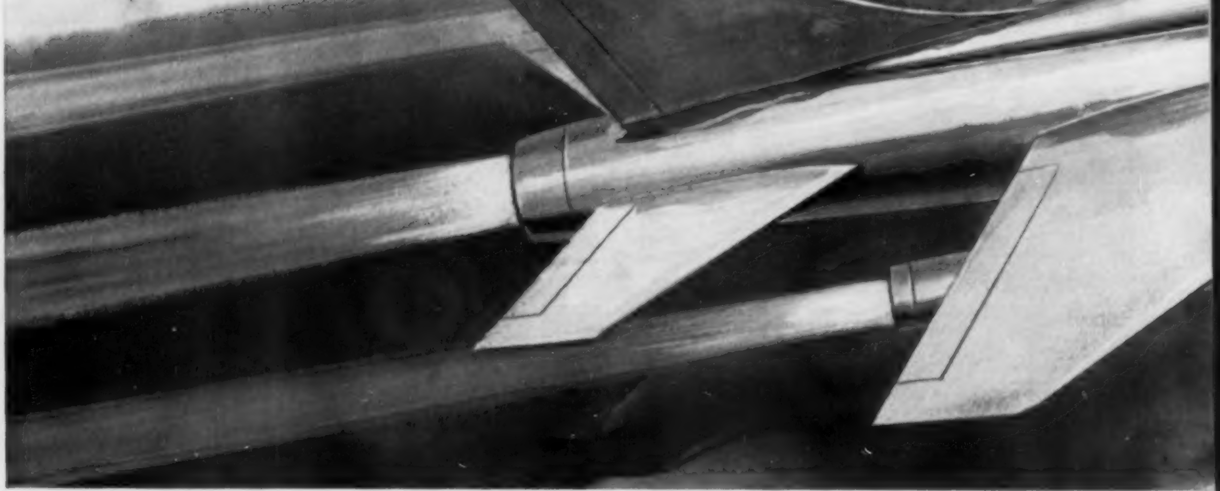
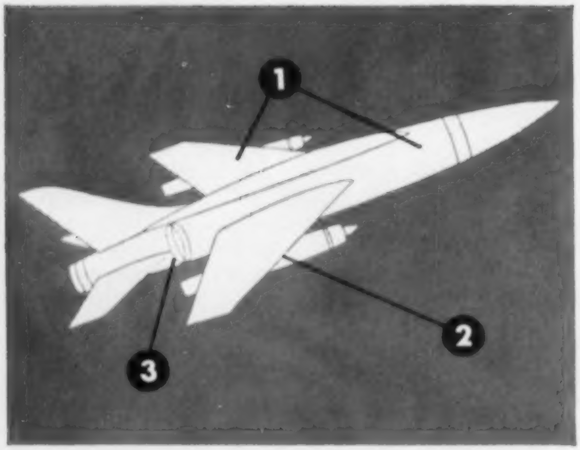
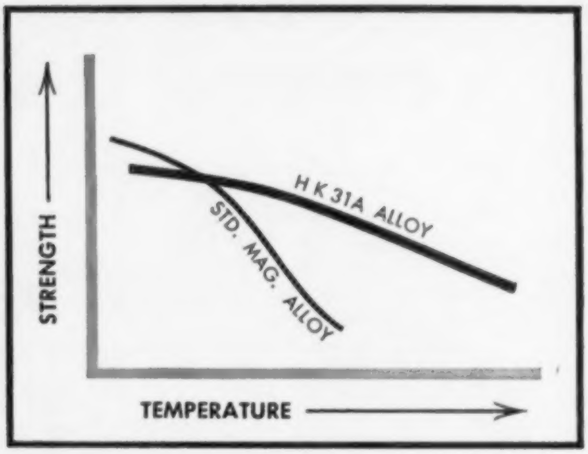
NEW DOW MAGNESIUM ALLOYS





Now suggested *for a broad range of uses in missiles and aircraft, the new Dow magnesium alloys are available in the form of (1) sheet or plate, (2) extrusions, (3) castings.*



Maintenance of strength *at high temperatures is illustrated by this chart. Performance data on the new alloys at elevated temperatures can be obtained by request.*

Aging . . .

2200° F. and the aging cycle at 1200 to 1600° F. for times up to 1000 hr.

Matrix lattice parameters of the alloys were measured with a back-reflection camera. Metallographic and electron microscope examinations were carried out on specimens electro-etched in 10% chromic acid. X-ray diffraction patterns of electrolytically extracted residues were obtained from selected specimens to aid in the phase identifications.

Increasing the time at solution temperature up to 72 hr. caused only small additional changes in the hardness and matrix lattice parameters of the alloys compared to the effect of increasing temperature. In general the principal precipitating phases, $M_{23}C_6$ and M_6C, can be progressively dissolved after 8 hr. at 2200° F. leaving the stable columbium phases Cb (C, N).

Short-time aging at all temperatures causes the formation of a fine well dispersed transition phase whose composition may be M_4C_3. Increasing time produces fine $M_{23}C_6$-type carbide precipitation within the austenitic matrix and along twin and grain boundaries. At the same time, some grain-boundary segregation and transformation to (Mo, W)-rich M_6C takes place. Longer aging times promote coalescence of smaller carbides at grain boundaries and the formation of a low-parameter M_6C (M_6C'). When insufficient carbon remains to allow continued carbide precipitation, a blocky phase appears within segregated regions which gives X-ray evidence of a Mg-Zn_2-type Laves phase.

There is a greater volume of Cb-(C, N) and less M_6C at grain-boundary junctions in solution treated G-18 B. The structural trends are similar to N-155 except that lamellar M_6C' appears only after long times at 1400° F. In these two alloys, sufficient carbon is available to avoid the presence of Laves phase. With the 15-15 N alloys, less initial Cb-(C, N) and fine M_6C can be seen and a small amount of $M_{23}C_6$-type carbide precipitation occurs at grain boundaries. In the later stages of aging the Laves phase appears.

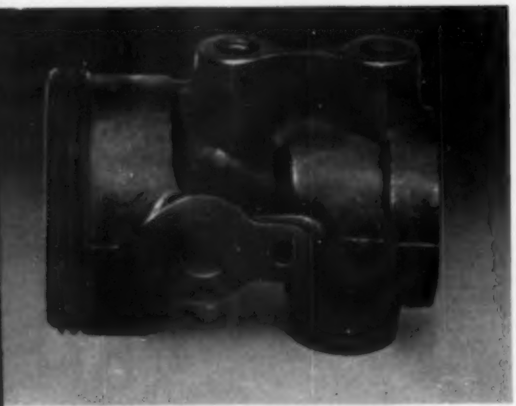
W. A. MORGAN

New High-Temperature Alloy

Digest of "An Austenitic Alloy for High-Temperature Use", by R. W. Guard and T. A. Prater. Preprint No. 32, 1956.

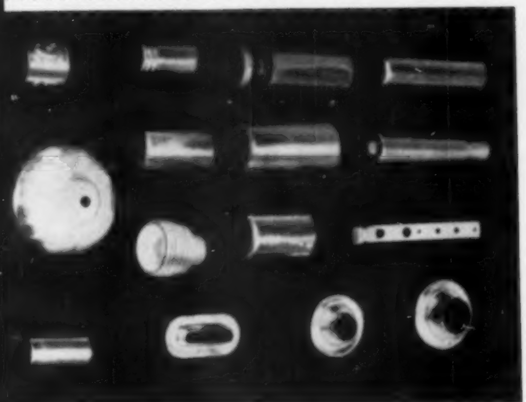
MOST austenitic alloys selected for use above 1500° F. derive their strength from precipitation hardening by carbides or Ni_3Al. Titanium, as Ni_3Ti, has been shown to be a relatively poor strengthener at high temperatures in nickel-base alloys. However, an earlier investigation indicated that in some cobalt-containing alloys it was possible to obtain satisfactory high-temperature properties in alloys containing titanium without aluminum. This paper describes investigations of the effects of composition, treatment and processing variables on a group of alloys contanining molybdenum, tungsten and titanium.

(Continued on p. 262)



Replaces Cadmium Plating . . . These grey cast iron valve bodies are used in the pneumatically operated sanders that deliver sand for improved traction under the wheels of trains, trolleys and trucks. Their manufacturer had a double-barreled problem . . . porosity in the castings was causing excessive rejects . . . expensive cadmium plating was necessary to prevent corrosion in service.

Steam treating has solved both problems in one operation. Rejects due to porosity have been eliminated, and many valves previously rejected have been salvaged. Cadmium plating has been eliminated entirely because exhaustive salt spray tests showed the steam-treated finish had a higher resistance to corrosion.

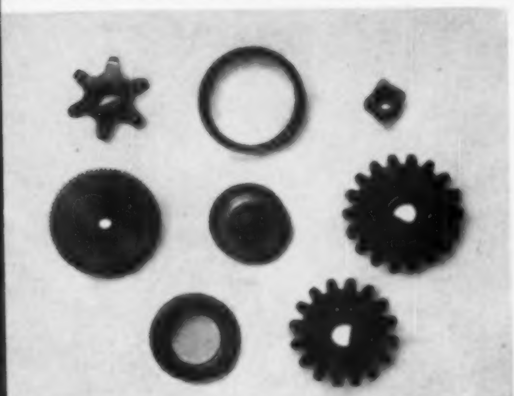


Cuts Expensive Pickling Costs . . . Non-ferrous lipstick tubes and other cosmetic containers made by a large Canadian manufacturer must be annealed before finishing operations can be performed. Scale was a problem. If left on, it ruined tools and dies . . . removing it meant expensive, messy pickling.

The solution was found when sample parts were annealed by the steam Homo* method. When this method was adopted as an integral part of the production line, pickling was eliminated. Subsequent figures from the cost-accounting department showed that eliminating this operation reduced annealing cost by 53 percent.

Puts "Extra-Life" in Cutting Tools . . . A machinery manufacturer faced a tough problem when specifications called for milling a 0.250 inch wide key-way slot into a piece of 4140 cold-rolled bar stock which was heat treated to a hardness of Rc 34 to 38. In addition, tolerances were tight . . . ±0.001 inch . . . with sides perfectly square.

The first high-speed steel tools used produced only four cuts and could not be resharpened because of the close tolerance. Hard-chroming the same tools improved cutter life to about 11 pieces per tool. Carbide tools held up for from 11 to 14 pieces. The next move was steam treating experimental batches of tools in an L&N furnace. The first batch averaged 100 parts per cutter, a second batch, 60 to 70 and a third lot, 100 to 125.



Raises "psi" of Powdered Iron Parts . . . Although many parts made of powdered iron function satisfactorily in the as-sintered condition, there are others where an increase in hardness and compressive strength is an advantage.

This is particularly true of such parts as the steam-treated gears, cams, etc., shown at left, where additional strength is needed on critical bearing surfaces. The shock-absorber piston in the center, for instance, presented a real problem . . . how to meet psi specifications for the thin-section flange around the outer edge. Steam treating proved a cheap, practical solution. Tests showed compressive strength of the flange increased from 1200 to 1400 psi. In addition, the parts, when oil dipped, had a pleasing uniform, blue-black color and high corrosion resistance.

New Alloy . . .

The precipitate present in the best alloys of the series, at least in the overaged condition, was identified as Ni_3Ti. The structure of this compound indicates it would probably take little molybdenum or tungsten into solution. At lower temperatures (1350° F.), the carbon in solution is precipitated as alloy carbides. It was found that the molybdenum, tungsten and iron content of the solid solution matrix were important in controlling the aging process.

Composition is the most important factor in determining rupture strength. Alloys with small amounts of iron resist loss in rupture life due to overaging much better than the alloys containing 20% iron. Iron content had little effect on the rupture ductility, however. Molybdenum and tungsten show similar beneficial effects on rupture ductility and rupture life. The effect of variations of titanium content or carbon content in the range of 0.4 to 1.0% is small.

The single alloy finally chosen for intensive investigation of the effects of processing variables contained 29% Ni, 19.9% Cr, 13% Fe, 6.6% W, 4.1% Ti, 3.9% Co and 0.20% C. Although it had been indicated by early testing that sufficient ductility could probably be obtained in any of the alloys, certain heat treatments resulted in low elongation and short fatigue life. Although the solution treating temperature was of greatest significance in determining the amount of ductility obtained during testing, aging temperature also had some effect. Aging treatment which produced the largest increase in rupture life and hardness resulted in low ductility. A high aging temperature (1650° F.) resulted in a structure which appears to be overaged but which showed a marked increase in tensile ductility with little sacrifice in rupture or tensile strength. The best heat treatment appears to be solution at 2100° F. and aging at 1650° F.

Mechanical properties of the alloy when solution treated and aged, and rupture lives and ductilities of ten heats of the alloy under various testing conditions are included in tabular and graphical form. At 1600° F. its 1000-hr. rupture strength is 15,500 psi.

E. S. RIDER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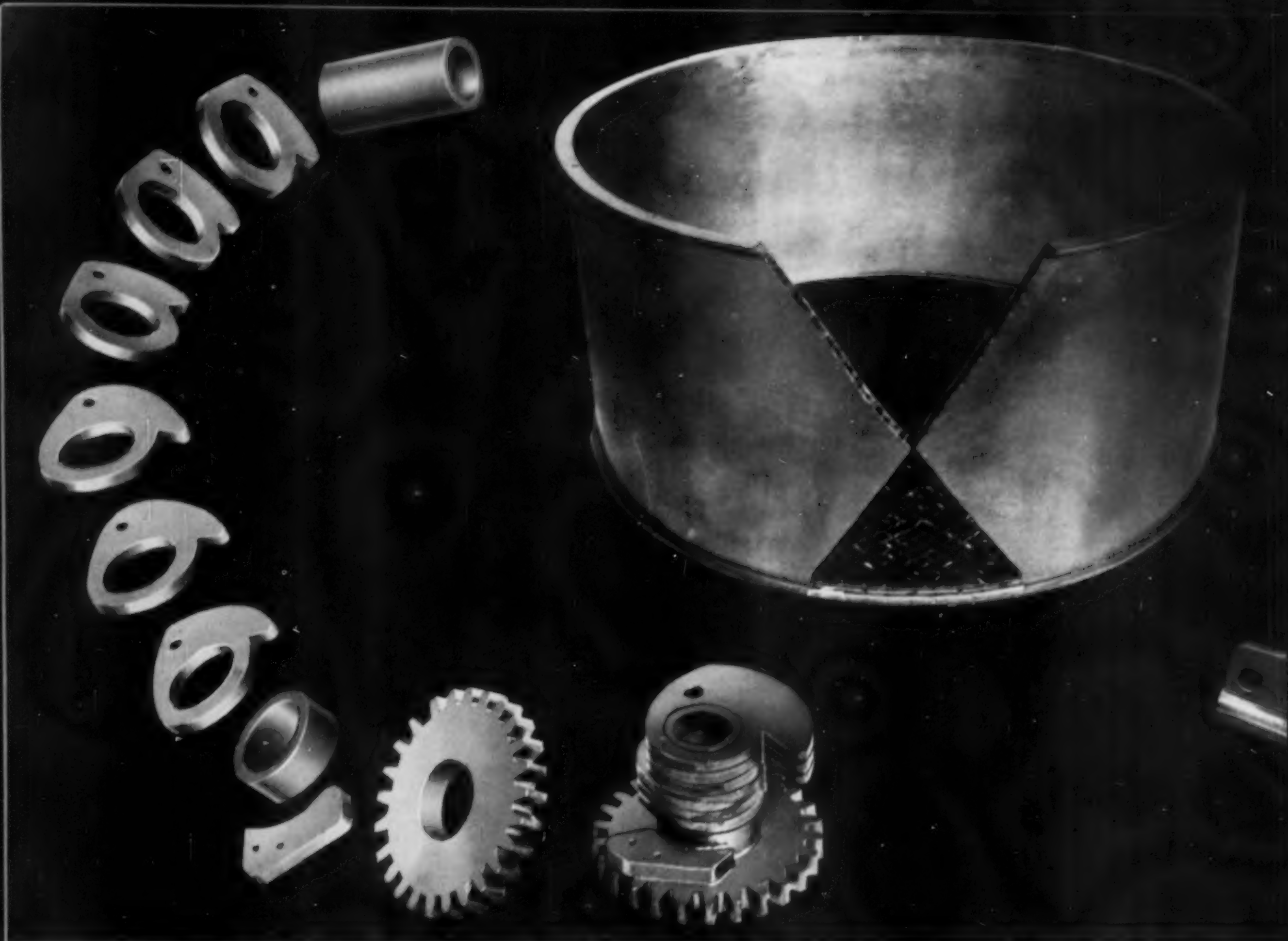
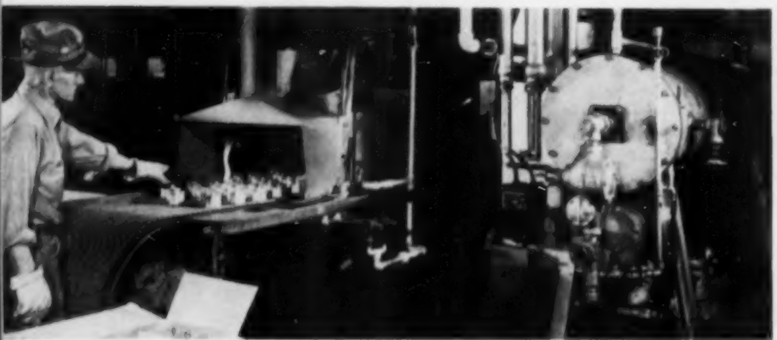


Versatility of furnace brazing is shown in these applications. Complex assemblies like the cam-and-gear cluster on the left can be fabricated from punched laminations brazed securely in a General Electric mesh-belt furnace. Required contours are obtained without expensive machining from solid stock.

Thin sections can be joined to heavy sections to produce light-weight rigid structures without sacrificing strength or inducing local distortion. Honeycomb structure at top center weighs about one fourth as much as solid assembly of same rigidity. It is typical of design improvements made possible by brazing in General Electric furnaces.



Continuous production of small parts in this General Electric mesh-belt furnace is carried out by loading assemblies directly on the belt. Protective atmosphere equipment, at right, eliminates need for flux in most cases, keeps parts clean enough to be passed directly from the furnace, without cleaning or pickling.

Automatic charging, and discharging and return conveyors of this General Electric roller-hearth furnace make it almost self-operating, reduces handling costs. G-E roller-hearth furnaces handle heavy assemblies and are well suited for automated lines.

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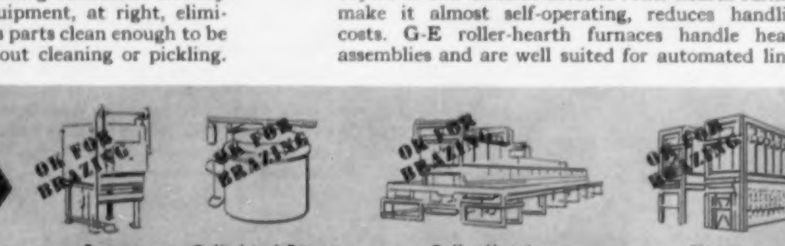

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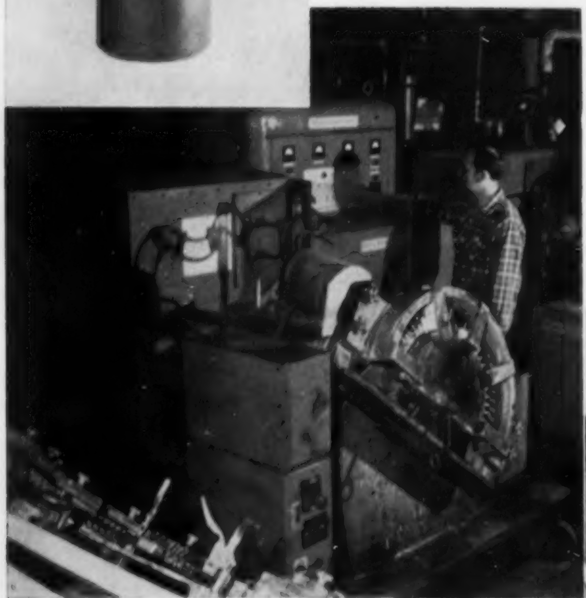
Each Curtiss-Wright J-65 turbojet engine uses 544 shrouded stator blades. Each blade must be positioned accurately and without physical distortion. Although brazing a single blade to the shroud ring is not difficult, it is quite a feat to perform rapid multi-blade brazing on a sustained production basis. Curtiss-Wright does just this in each of its three induction heating stations, each powered by two Machlett ML-5668 induction heater triodes.



*Machlett induction heater triodes are original equipment in over 75% of the induction heating equipment models now available in the 5kW to 100kW power output range. . . . Proof enough of Machlett electron tube quality and performance!

Top – ML-5668 Induction Heater Triode

Center – One of three induction heating stations used for production brazing of stator assemblies used in Curtiss-Wright's J-65 turbojet engine.

Bottom – Stator assembling jig for Curtiss-Wright's J-65 turbojet engine.

***ML-5668** Original Machlett electron tube design; heavy duty triode replacement for old design, light construction type 892 tube.

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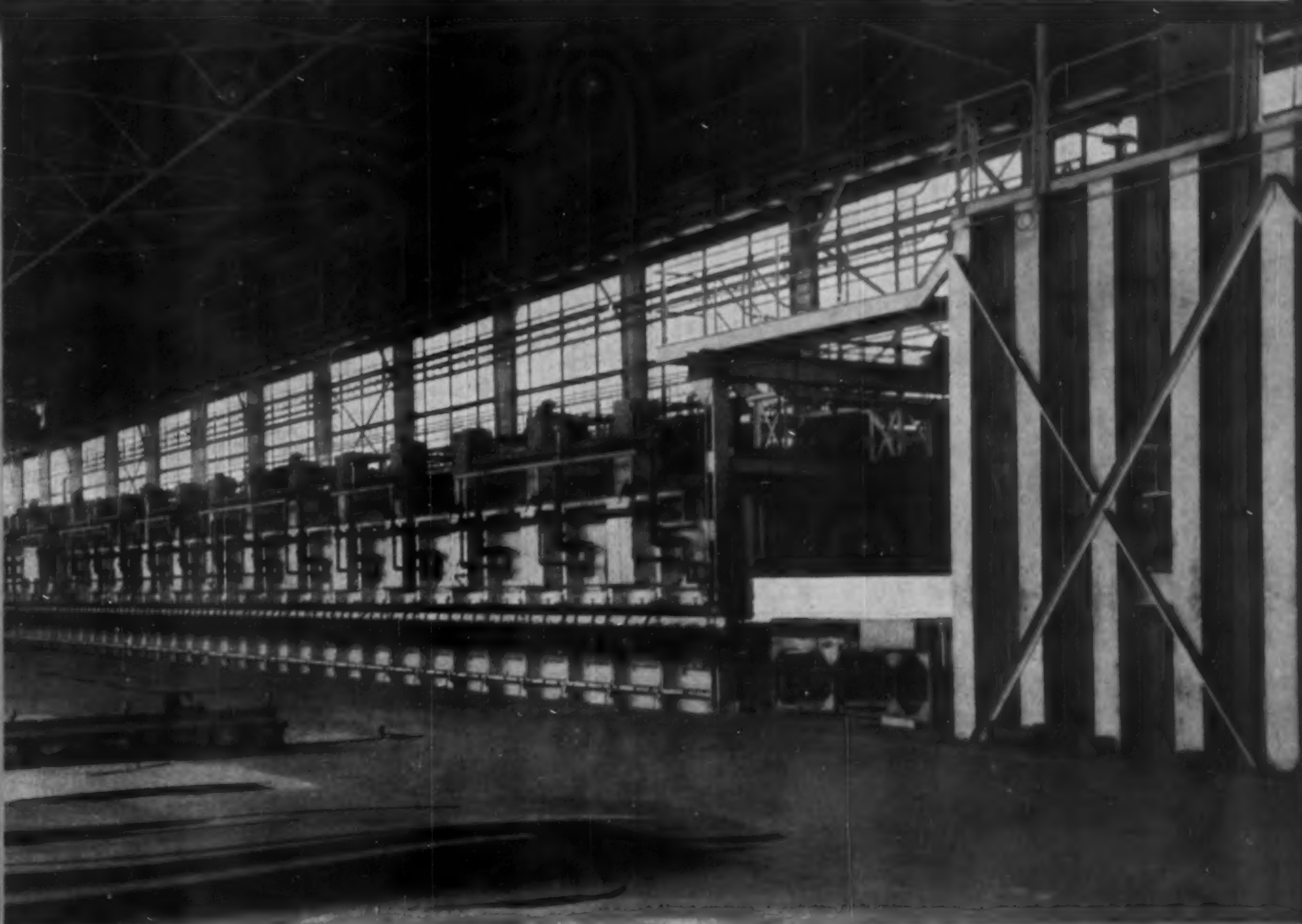

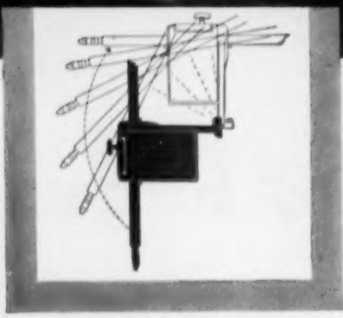

New Airco Model C Heliweld automatic head operates at all angles from horizontal to vertical.

Airco introduces New Automatic Heliweld Head for long-run production welding

The Model C Heliweld automatic head is specifically designed for long-run production on regular or irregular contours — aluminum tubing, motor stators, irregularly-shaped pressure vessels. Its prime advantage is that once the required arc length is set the head will automatically maintain this distance by moving the holder up or down to follow the contours of the work piece. Other benefits are:

- **Versatility** — unit provides good arc voltage control using either argon or helium shielding gases or mixture of both.
- **Adaptability** — the head can be operated at all angles from the horizontal to the vertical (normal) position. The maximum raise-lower distance of the electrode holder is a full 16".
- **Flexibility** — the assembly can be used for AC or DC welding, with or without filler wire. Electrode diameters range from .020 to ⅛".

The use of the new automatic head will be required where welds of consistent dimensions and quality are important and where good weld appearance is necessary or where welding specifications are very high for the electrical, aircraft, and refrigeration industries. Complete information covering the wide range of applications and detailed specification data is available. Write Airco at the first opportunity.

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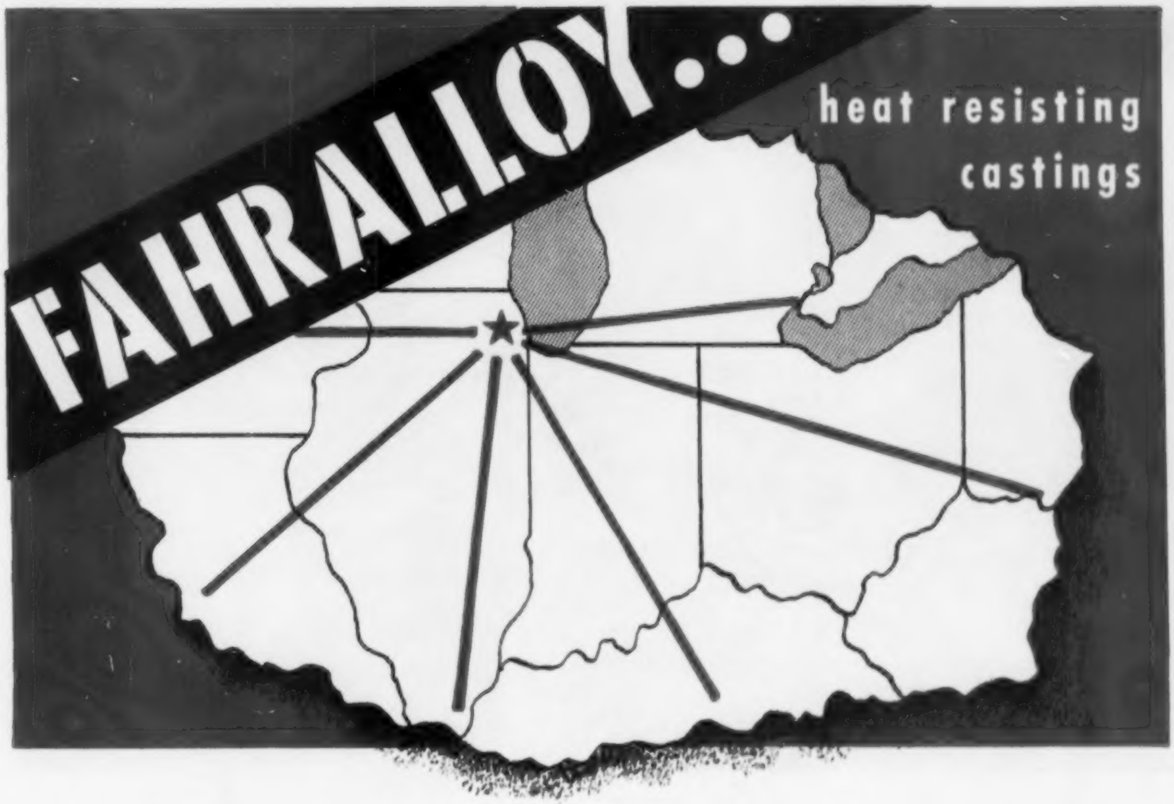

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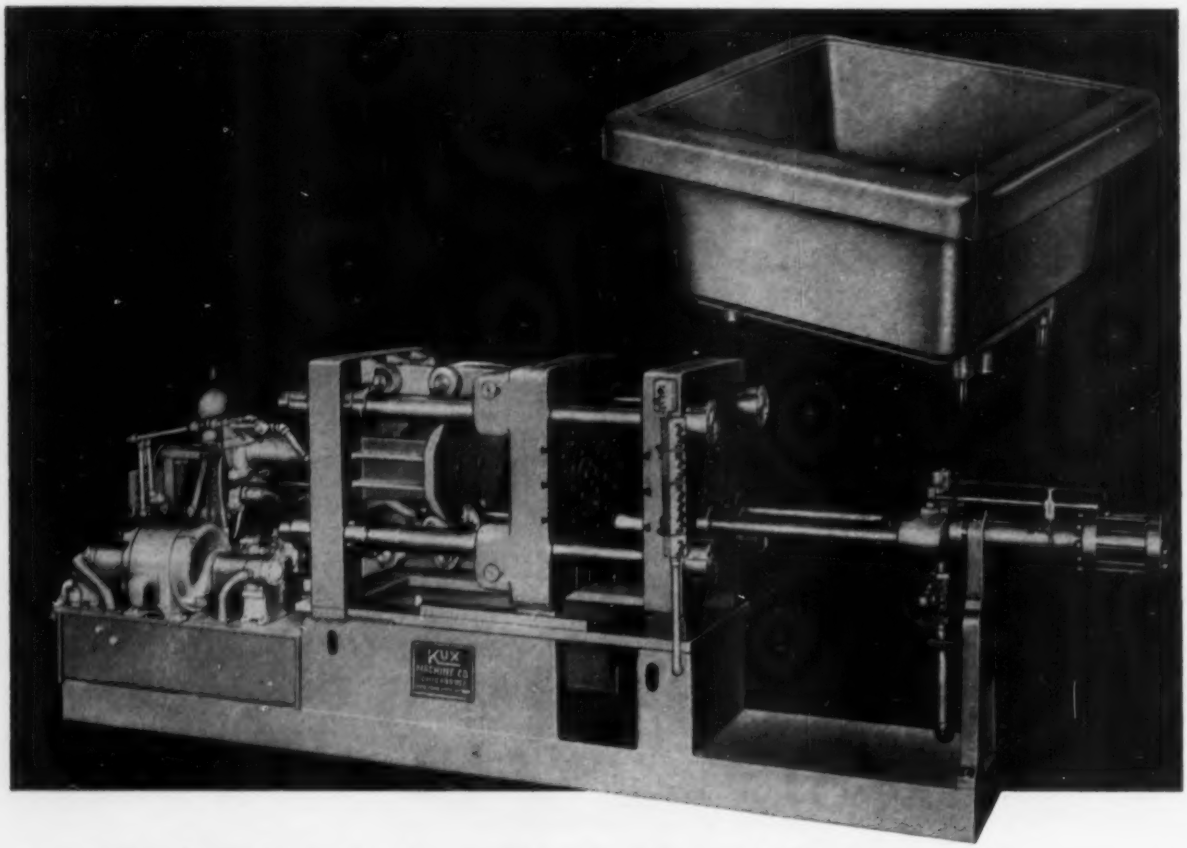

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"The hardware finish quality castings provided by KUX machines eliminates many polishing and finishing operations and leaves the fry well easy for the housewife to clean."

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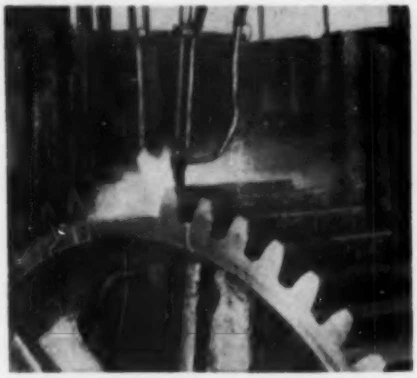

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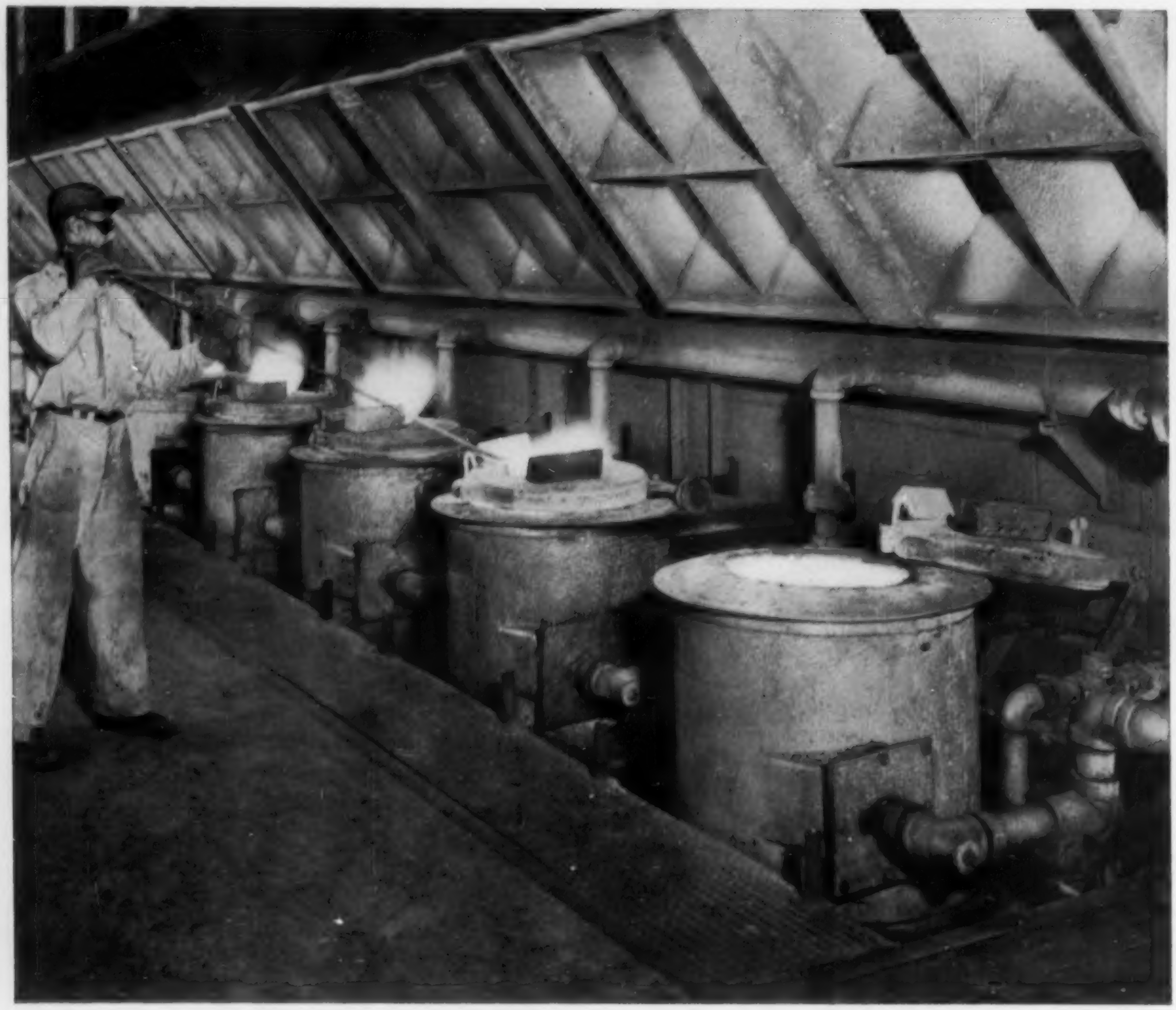


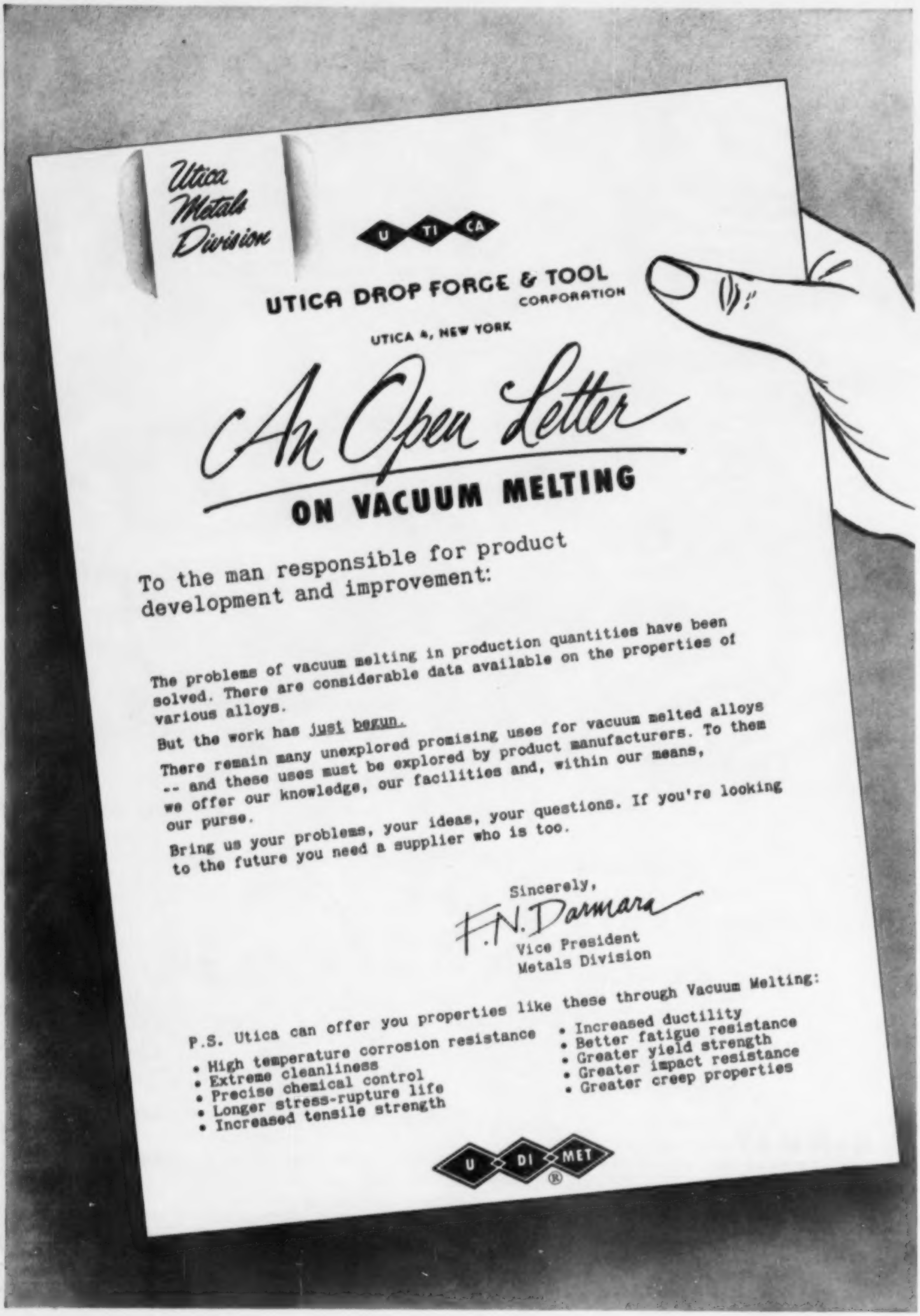
Improved working conditions, less maintenance, longer life for crucibles and furnace linings . . . thanks to GAS

Fischer Casting Company, Inc.
Middlesex, New Jersey

When Fischer Casting Company, Middlesex, New Jersey, moved into their modern new plant, they chose Gas for all their melting facilities.

With Gas operation of all furnaces, closer melting controls are possible. Clean burning Gas, along with modern ventilating equipment, has resulted in better working conditions in melting departments. Furthermore, in the bronze melting department, improvement is shown in the life of furnace refractories and crucibles. Gas also improves the melting operations in the aluminum sand foundry and permanent mold melting divisions. Three Gas-fired immersion burners heat an 860 gallon quenching tank to 212 degrees F. and one immersion burner maintains this temperature to provide a simple, dependable and accurate method of quenching aluminum castings.

For information on how you can improve your production operations by using Gas, call your Gas Company's industrial specialist. He'll be glad to discuss the economies and outstanding results you get with Gas and modern Gas-fired industrial equipment. *American Gas Association.*



Utica Metals Division

U TI CA

UTICA DROP FORGE & TOOL CORPORATION

UTICA 4, NEW YORK

An Open Letter

ON VACUUM MELTING

To the man responsible for product development and improvement:

The problems of vacuum melting in production quantities have been solved. There are considerable data available on the properties of various alloys.

But the work has just begun.

There remain many unexplored promising uses for vacuum melted alloys -- and these uses must be explored by product manufacturers. To them we offer our knowledge, our facilities and, within our means, our purse.

Bring us your problems, your ideas, your questions. If you're looking to the future you need a supplier who is too.

Sincerely,

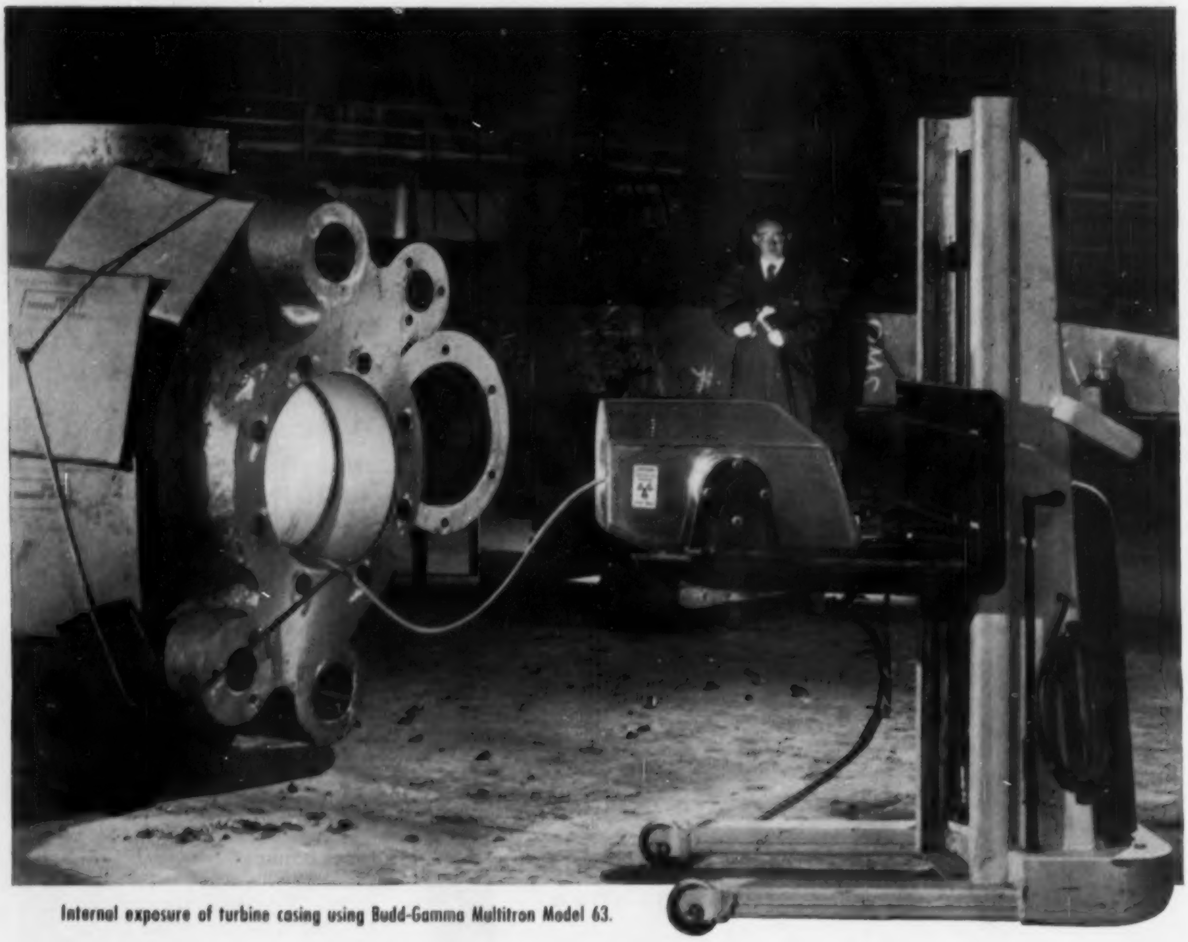
F.N. Darmara

Vice President
Metals Division

P.S. Utica can offer you properties like these through Vacuum Melting:

- High temperature corrosion resistance
- Extreme cleanliness
- Precise chemical control
- Longer stress-rupture life
- Increased tensile strength
- Increased ductility
- Better fatigue resistance
- Greater yield strength
- Greater impact resistance
- Greater creep properties

U DI MET ®



Internal exposure of turbine casing using Budd-Gamma Multitron Model 63.

Budd provides complete Gamma Isotope Radiography Service

The physical and technical resources of The Budd Company are now being directed to the development and manufacture of gamma isotope radiography units.

These units are designed to employ any of the established gamma ray sources, of any required strength, and to provide for panoramic, beam and internal shots.

They are portable and can be operated by one man. They require no attachment to electrical or water lines, consequently they can be used anywhere. They are fast. Accurate. Economical. Safe.

Budd will train your operating personnel in the use of these devices, and also provides a service for the replacement of gamma sources at scheduled intervals.

For catalogue and complete information, address The Budd Company, Gamma Division, Philadelphia 32.

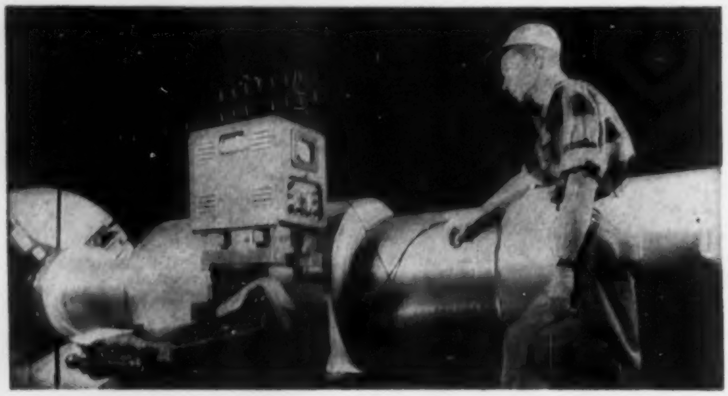
Budd

Visit our Booth 1707 at the Metal Show

Sperry

ultrasonic inspection news

HOW ULTRASONIC TESTING HELPS U. S. STEEL PRODUCE FLAWLESS FORGINGS!



This turbine generator shaft—forged and sonic-tested by U. S. Steel — is part of the first nuclear reactor power plant to be built in the United States. The 60,000 kilowatt power plant will go into operation in 1957.

Here, the shaft is being Reflectoscope-tested while it is still in the lathe. The forging will be sonic-tested a *minimum of 5 times* as it progresses through various stages of manufacturing. At U. S. Steel, turbine and generator rotor forgings are tested at these stages:

1. Preliminary sonic test is run on the rough forgings before machining.
2. Forging is rough-turned to bring it into a "round," then sonic-tested again.
3. After a bore has been drilled through the forging, it gets a complete full-scale sonic inspection.
4. After grain-refining (heat-treatment) another sonic test is made.
5. After finish-machining and stress-relieving, the forging is inspected again as specified by the customer.

All these sonic inspections are usually conducted while the forging is rotating, except for the as-forged test. A carbide tool finish is used to provide a suitable surface for the double-crystal search unit.

This testing for defects before forgings are placed in actual operation enables U. S. Steel to turn out flawless forgings that *exactly* meet ASTM and customer requirements. Reflectoscope inspection saves U. S. Steel man-hours and money...helps assure customer satisfaction! It can do as much for you. Use the handy coupon to ask for full information.

THE SHOW'S ON THE ROAD!

Sperry's new ULTRASONIC CARAVAN is now on a nationwide tour of plants and factories throughout the United States.

The Caravan's compact exhibits will demonstrate every aspect of ultrasonic testing and equipment to management and engineering personnel. You will see all types of Sperry Reflectoscopes, signaling and recording devices — in action...in your own plant...using samples of your own materials or products for testing!

If you are located in one of the nation's larger industrial centers, the ULTRASONIC CARAVAN is probably already scheduled to visit your plant. If not, your Sperry Representative will be glad to discuss the possibility of a visit to your plant or area. Return coupon for itinerary of the ULTRASONIC CARAVAN.

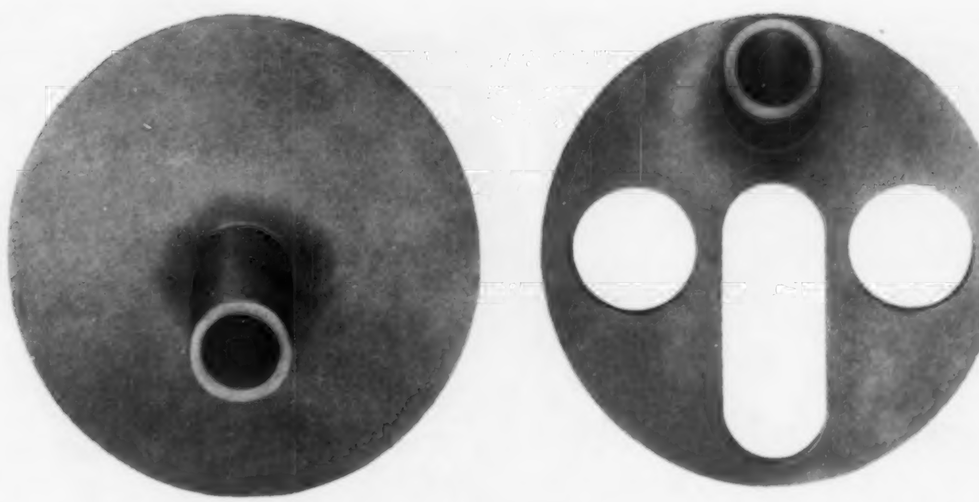
Sperry Products, Inc.
600 Shelter Rock Road
Danbury, Connecticut

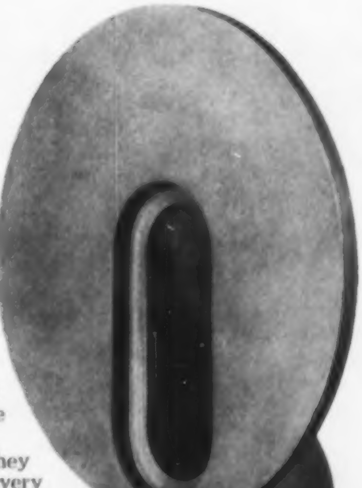
Please tell me when the Ultrasonic Caravan will be in my area.

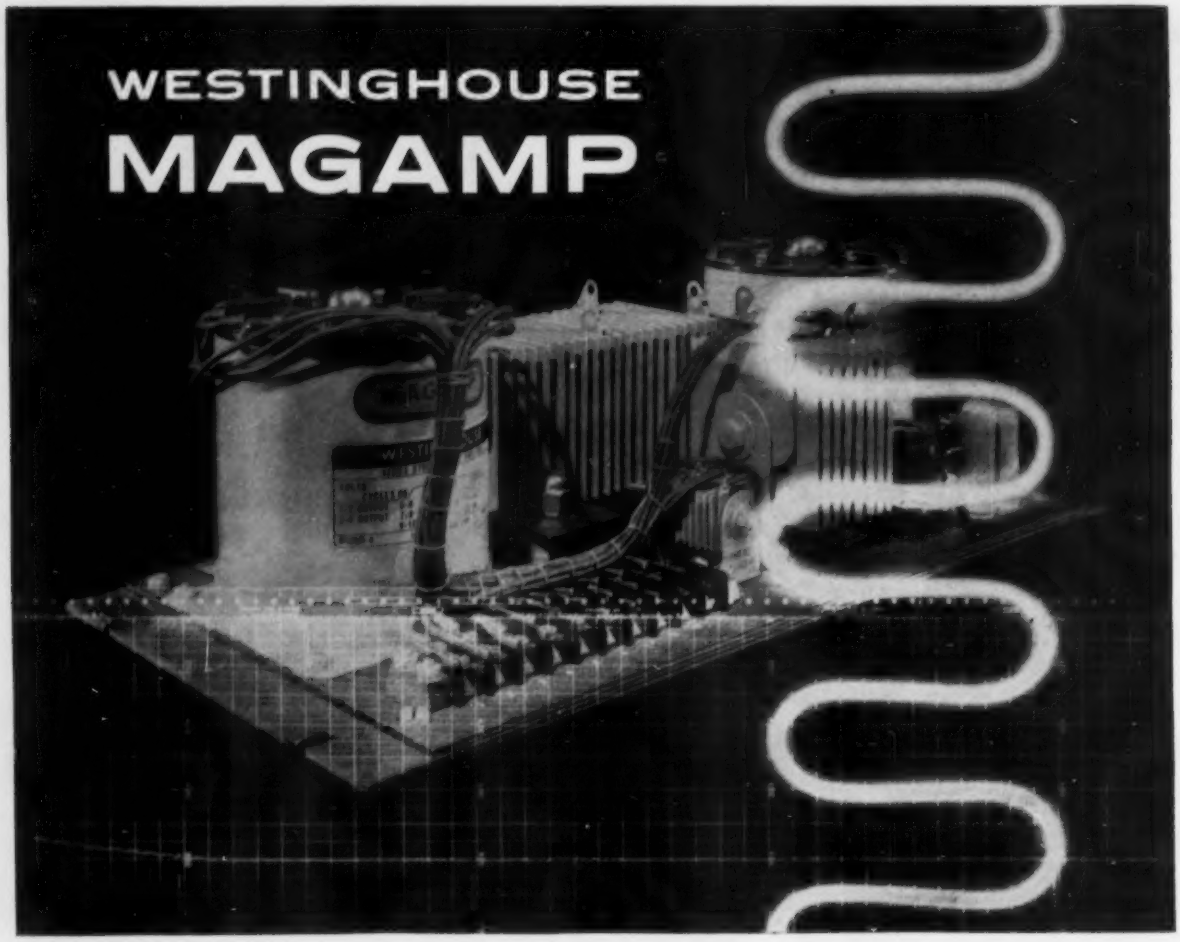
Name__________
Title__________
Company__________
Address__________
City_____ Zone____ State_____

sperry products INC.

FIRST IN ULTRASONIC INSPECTION







Links temperature control with ten times longer life

With Westinghouse Magamp* magnetic amplifiers you can assure extraordinary predictable life for the critical job of amplifying temperature control signals; plus the fact that Magamp controls bring significant dollar savings.

Actually, these link units are rated for at least 20 years of stable, trouble-free service. They are unaffected by heat, dirt or corrosive atmospheres and have no moving parts to stick or jam. In standard panel assemblies, you can apply Magamps for control on industrial furnaces regardless of size.

In most cases, Magamp link units offer first cost savings of up to 50% over conventional controls. You'll see lower lifetime costs, too, since Magamp eliminates replacement and maintenance expense of conventional electronic controls.

Further facts, ratings, and application data for standard Magamp link units are yours in a free Facts Folder. Contact your local Westinghouse sales engineer, or write: Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania.

*Trade-Mark
J-01006

WATCH WESTINGHOUSE!

WHERE BIG THINGS ARE HAPPENING TODAY!

Bunting® Products

CAST BRONZE BEARINGS AND PARTS

SINTERED POWDERED METAL BEARINGS (Oil-Filled) AND SINTERED POWDERED METAL PARTS

STANDARD STOCK BEARINGS

854 stock sizes Finished Cast Bronze Bearings for all applications.

PRECISION BRONZE BARS

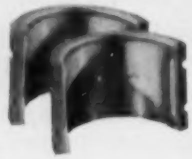
263 stock sizes Tubular and Solid Cast Bronze Bars. Fully machined. 13'' long.

ELECTRIC MOTOR BEARINGS

324 stock sizes Finished Cast Bronze Bearings ready for assembly in all popular motors.

SPECIAL BEARINGS

Cast Bronze Bearings and Parts made to customers' blueprints. Send specifications, quantities, material analysis and design to Toledo for prices or recommendations. Engineering services always available.

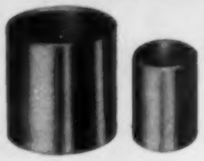


BABBITT LINED BEARINGS

Cast Bronze with centrifugally cast linings of tin or lead base Babbitt. Send inquiry and specifications to Toledo.

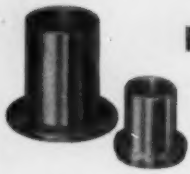
GRAPHITED OIL-LESS BEARINGS

Cast Bronze Bearings grooved and graphited for special applications.



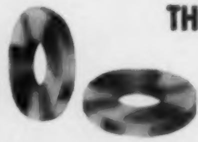
PLAIN STOCK BEARINGS

553 stock sizes Finished Sintered Bronze Plain Bearings made to ASTM standard sizes, dimensions and tolerances.



FLANGE STOCK BEARINGS

86 stock sizes Sintered Bronze Flange Bearings made to standard dimensions and tolerances.



THRUST BEARINGS

28 stock sizes Sintered Bronze Thrust Bearings made to standard dimensions and tolerances.

SINTERED POWDERED BRONZE BARS

62 stock sizes tubular bars and 22 stock sizes solid bars. 6½'' long.

SPECIAL BEARINGS

Sintered Powdered Bronze Bearings made to customers' blueprints. Send specifications, quantities, material analysis and design to Toledo for prices or recommendations. Engineering service always available.

SPECIAL SINTERED PARTS OF BRONZE OR IRON

Sintered Powdered Metal Parts of bronze or iron made to customers' blueprints. Send specifications, quantities, material analysis and design to Toledo for prices or recommendations. Engineering service always available.

All stock sizes above listed are available from distributors everywhere in the United States. Catalogs on request. Bunting machine shops in New York City, Chicago, Detroit and Atlanta provide quick service for alterations, grooving and graphiting.

The Bunting Brass and Bronze Company

TOLEDO 1, OHIO • BRANCHES IN PRINCIPAL CITIES

15 times the life in Acid Mixtures

AND STILL GOING STRONG

PROBLEM:

Baskets for submerging alloy steel forgings in hot pickling acids had to be replaced every month because of severe corrosion. The baskets were continually immersed in either 15 per cent hydrochloric acid, aqua regia, 10 per cent nitric and hydrofluoric acids, or 20 per cent nitric acid. All of these acids were at about 140 deg. F.

REMEDY:

The baskets were made of one-inch round bars of HASTELLOY alloy C.

RESULT:

After 15 months' service, three shifts a day, the baskets made of HASTELLOY alloy C are still good.

HASTELLOY alloy C is the most universally corrosion-resistant alloy available today. It has high-strength and is highly resistant to all of the mineral acids. For a copy of a booklet describing HASTELLOY alloys, get in touch with the nearest Haynes Stellite Company office.

HAYNES
TRADE-MARK
ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

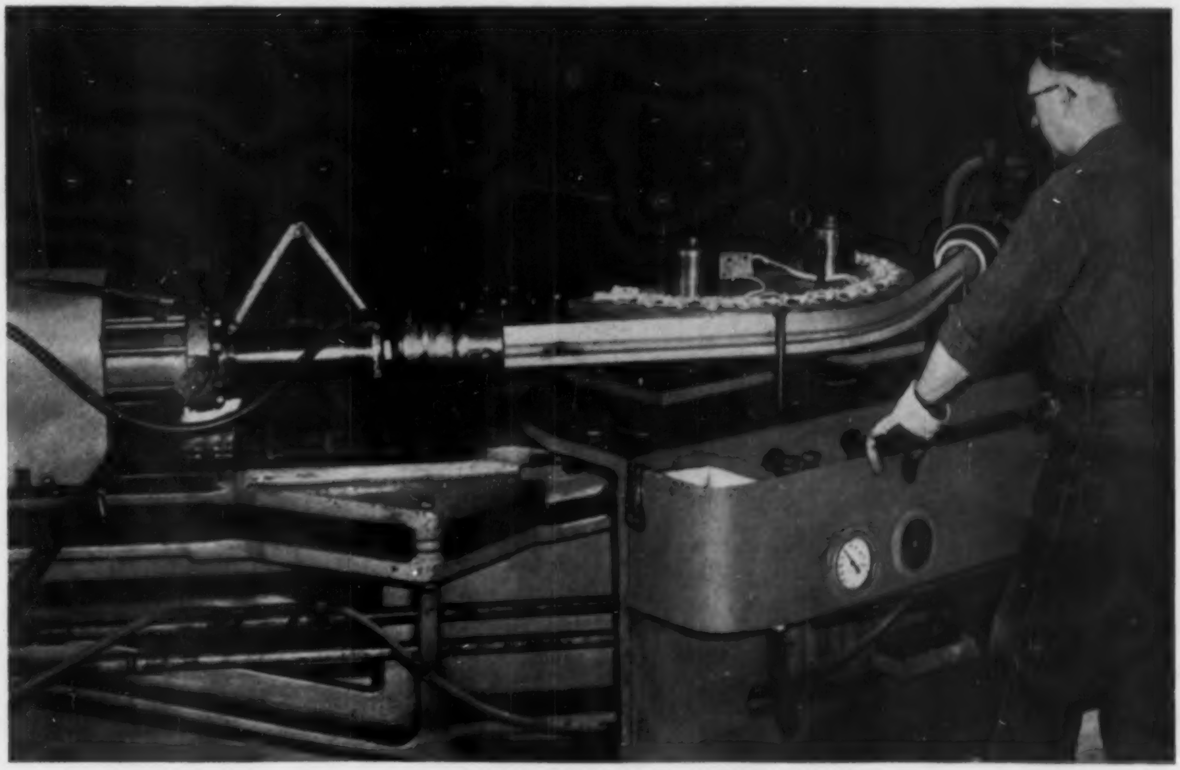
General Offices and Works, Kokomo, Indiana

Sales Offices

Chicago • Cleveland • Detroit • Houston • Los Angeles • New York • San Francisco • Tulsa

"Haynes" and "Hastelloy" are registered trade-marks of Union Carbide and Carbon Corporation.

MALLORY·SHARON reports on TITANIUM



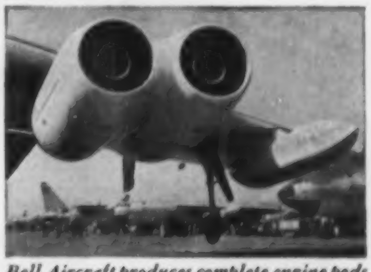
Certified titanium strength helps Bell Aircraft cut fabrication time

● In stretch forming titanium sheet parts, Bell Aircraft found variable springback an annoying problem—requiring expensive hand line-up and re-working. Springback variations of several degrees were encountered with sheets of different strength levels.

Mallory-Sharon's strength certification has aided Bell's successful effort to reduce time, work and scrap loss in titanium fabrication. Using statistical quality control, we certify the average strength of each titanium heat, and further certify that 97.5% of the heat lies within narrow limits of this value (such as ± 5000 psi).

This simplifies segregation of incoming material into close strength ranges. Bell color codes and handles each strength level separately. In addition, hot forming techniques have been perfected to reduce variable springback.

Quality certification is *another first* from Mallory-Sharon contributing to the rapid advance of this new metal. Call us for your requirements in titanium and titanium alloy mill products, and for technical assistance in application.

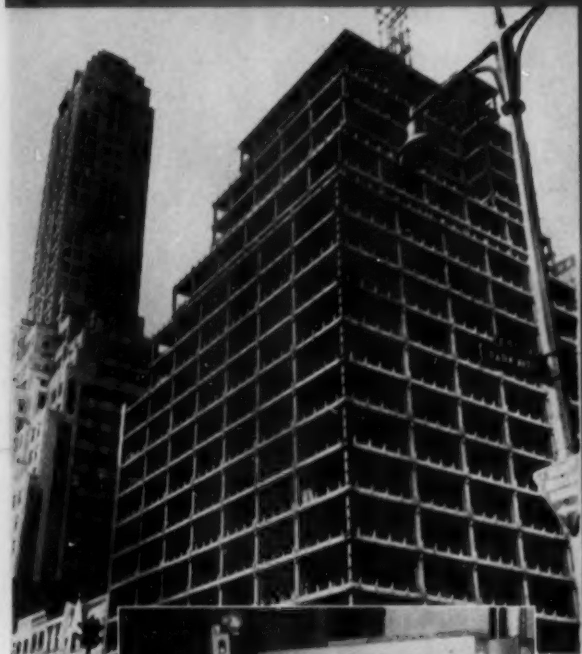


Bell Aircraft produces complete engine pods for the Boeing B-52 jet bomber. Extensive use of titanium in these pods saves approximately 400 pounds gross.

MALLORY-SHARON TITANIUM CORPORATION, NILES, OHIO

MALLORY Ti SHARON

Curtain Going Up!



The *Marion Davies* Building, New York, was completely enclosed in *10 hours*—through the miracle of anodized aluminum "curtain" walls. Giant two-story panels are manufactured by General Bronze Corp., using an **H-VW-M AUTOMATIC ANODIZING SYSTEM.**

General Bronze Corp. led the field when they anticipated the vastly increased use of anodized aluminum in the building industry. The same wisdom and foresight motivated General Bronze when they called on H-VW-M to supply their giant, streamlined new anodizing system. **H-VW-M DESIGNED, MANUFACTURED AND INSTALLED** it from beginning to end. And the benefits to General Bronze: tripled production . . . improved quality control . . . and the assurance that H-VW-M—the **ONE SOURCE** they chose—assumed **COMPLETE RESPONSIBILITY** for the entire system, from concept to production.

PLATEMANSHIP

Your H-VW-M combination—of the most modern testing and development laboratory—of over 80 years experience in every phase of plating and polishing—of a complete equipment, process and supply line for every need.

HANSON-VAN WINKLE-MUNNING COMPANY, MATAWAN, N. J.

Plants: Matawan, N. J. • Grand Rapids, Mich.

SALES OFFICES: Anderson (Ind.) • Baltimore • Beloit (Wisc.) Boston • Bridgeport • Chicago • Cleveland • Dayton • Detroit Grand Rapids • Los Angeles • Louisville • Matawan Milwaukee • New York • Philadelphia • Pittsburgh • Plainfield Rochester • St. Louis • San Francisco • Springfield (Mass.) Utica • Wallingford (Conn.)

H-VW-M

INDUSTRY'S WORKSHOP FOR THE FINEST IN PLATING AND POLISHING PROCESSES • EQUIPMENT • SUPPLIES

UNICHROME
Trade Mark

News about COATINGS for METALS

Metallic . . . . . . Organic . . . . Decorative . . . . Protective

New process gives more corrosion-proof chromium plated finish

Top: (Left) After many months outdoors, a .0005" deposit of ordinary chromium, plated directly on steel, was rust-covered; (Right) Crack-Free Chromium, same thickness, was virtually unaffected. Bottom: (Left) Photomicrograph of etched ordinary chromium shows network of microscopic cracks. (Right) Etched Crack-Free Chromium deposit shows no such imperfection.

Experience with a relatively new kind of chromium finish reveals a most important difference in serviceability. This difference is graphically shown above. Unichrome Crack-Free Chromium Plating proves definitely, measurably superior to ordinary chromium for certain types of applications . . . notably those where durability and protection are paramount.

REASONS WHY

Crack-Free Chromium is *structurally* different from ordinary chromium plate. It does not develop the typical network of microscopic cracks—even in thicknesses specified for "hard" chromium plating. Corrosives find no path to the underlying base metal. Rusting is blocked.

Crack-Free Chromium can be plated directly on steel or zinc base die castings. It does not depend on an undercoat of scarce nickel for long life.

OTHER ADVANTAGES

In other ways, too, the new finish proves superior to ordinary chromium. It resists thermal shock and gives better protection at elevated temperatures. It gives improved non galling, non seizing properties.

Designers who want to give parts solid protection against corrosive conditions will find Crack-Free Chromium well worth evaluation. Send for Bulletin CFC-1.

Protective coating 60 mils thick or more with one spraying

Another improvement in plastisol coatings has again been achieved. Unichrome "Super 5300" Coating delivers the full solids content of vinyl plastisol through a spray gun and builds up a coat 60 mils thick or more in one application. Thinner coatings, too, if desired.

The coating is physically tough and flexible. It doesn't chip or tear. It has the chemical resistance as well as the thickness to withstand acids, alkalies, salt solutions, moisture and other corrosives. It offers better protection for metals with a seamless and pore-free heavy duty coating. Send for Bulletin SP-1.

Unichrome is a trademark of Metal & Thermit Corp.

METAL & THERMIT
CORPORATION

General Offices: Rahway, New Jersey
Pittsburgh • Atlanta • Detroit
East Chicago • Los Angeles
In Canada: Metal & Thermit—United Chromium of Canada, Limited, Toronto 1, Ont.

NEW BOOKLET DESCRIBES LATEST USES FOR STRAITS TIN IN MAJOR INDUSTRIES

Reviews Most Recent Product-Improving, Cost-Reducing Applications. Send for Your Free Copy Now!

This new booklet contains up-to-the-minute information about one of our most useful metals — Straits Tin from Malaya. Booklet explains why tin's properties make it so important to American industry, gives specific examples of new applications solving various manufacturing problems. Sixteen pages, fully illustrated, factual and concise. Write now for your free copy of "STRAITS TIN FROM MALAYA, Its New Importance to American Industry."

The Malayan Tin Bureau
Dept. 25J, 1028 Connecticut Ave.
Washington 6, D.C.

Please send me a free copy of the new booklet, "STRAITS TIN FROM MALAYA, Its New Importance to American Industry."

Name and Position____________________

Company____________________

Street____________________

City__________ Zone_____ State_____

The Malayan Tin Bureau

Dept. 25J, 1028 Connecticut Ave., Washington 6, D.C.

INSULATING FIRE BRICK	Temp. Limit	Density (lb/cu ft)	Strength (cold crushing, psi)	Conductivity (Btu in, sq ft F hr at 1000F mean temp)
JM-3000	3000F*	64	400	3.20
JM-28	2800F*	58	150	2.50
JM-26	2600F*	48	190	2.22
JM-23	2300F*	42	170	1.91
JM-20	2000F*	35	115	1.22
JM-1620	1600F* / 2000F**	29	70	1.02
Sil-O-Cel* Super	2500F**	40	300	1.95
Sil-O-Cel C-22	2000F**	38	700	1.88
Sil-O-Cel 16L	1600F*	34	350	1.07

*Back-up or exposed
**Back-up only

From Johns-Manville refractory research...

insulating fire brick with balanced properties for unsurpassed heat-control effectiveness

The nine types of insulating fire brick produced by Johns-Manville offer furnace builders and operators a common advantage—*balanced properties!*

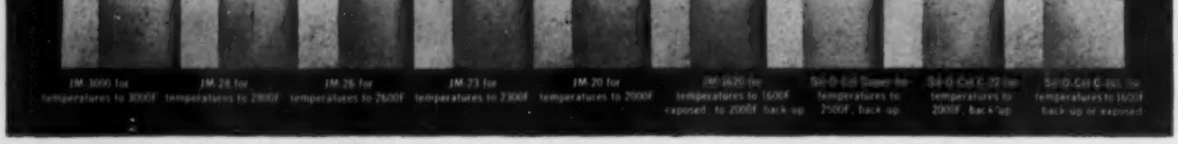
The Johns-Manville insulating brick formulated for your service gives you the ideal combination of physical and thermal properties without sacrificing one for the other. This means you get unsurpassed heat-control effectiveness . . . greater economy in furnace design . . . hours saved in reaching operating temperatures!

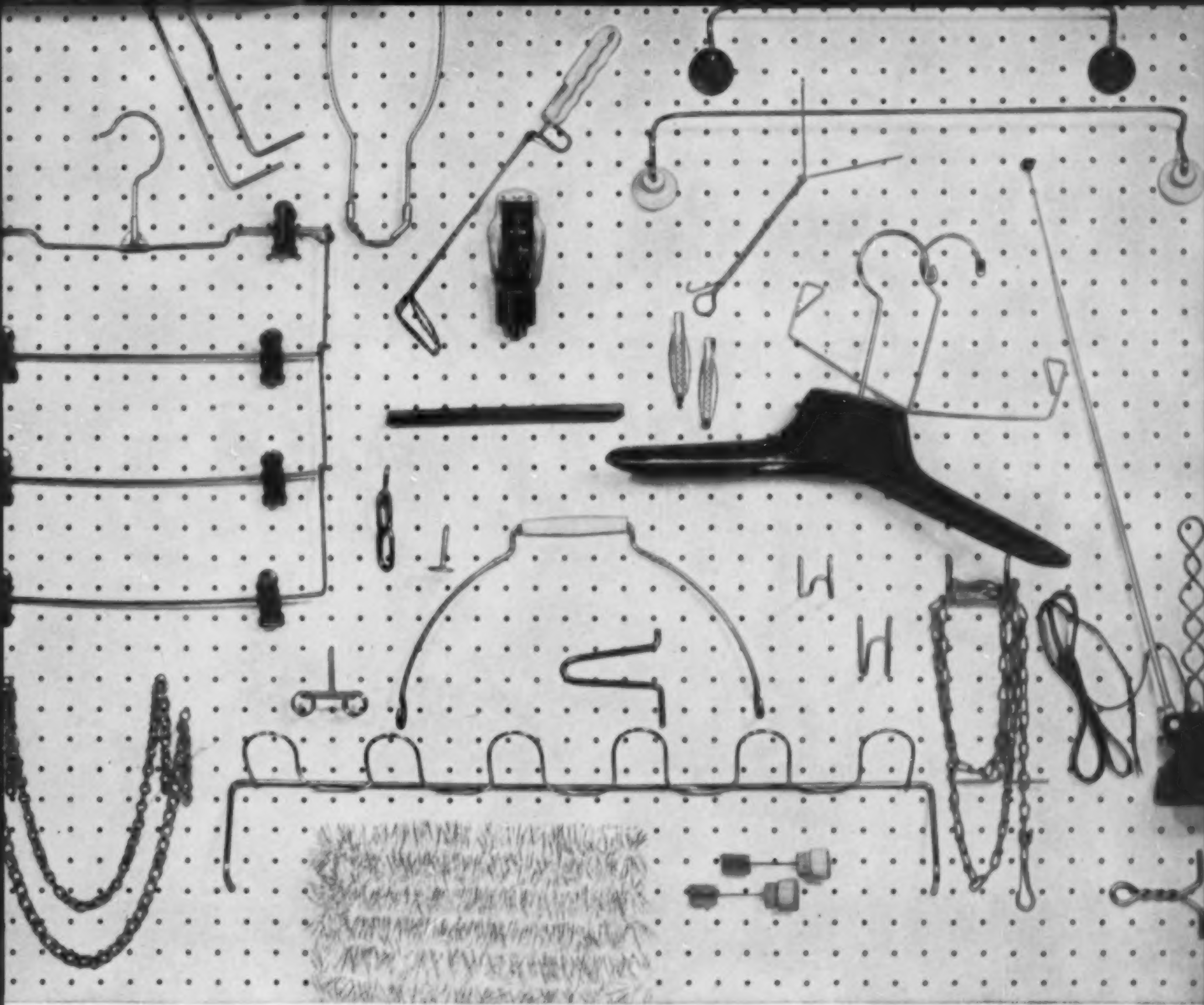
For a good example of the value of *balanced properties*, take the proved performance of JM-3000 insulating fire brick. Formulated for 3000F temperature service, this insulating fire brick has unusual load bearing strength, high spall resistance, low shrinkage and thermal conductivity proportionate to its density.

Johns-Manville has two strategically located plants for the production of insulating brick: Lompoc, California and Zelienople, Pennsylvania. Insulating brick are available from the stocks of authorized J-M distributors in key industrial areas.

For complete information, call your nearest J-M representative. Or write for brochure IN-115A to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

JM Johns-Manville REFRACTORY AND INSULATING REFRACTORY PRODUCTS





How these products were improved and costs lowered . . . with NICKELPLY*, BRASSPLY* and COPPERPLY* wire!

• National-Standard Nickelply, Brassply and Copperply is electro-jacketed steel wire—a new development offering important advantages to manufacturers and users of wire forms and components. Specifically . . . . .

The jacket metal, precisely concentric and to the required thickness, *is inseparably bonded to the steel wire.* The materials can be severely formed, twisted, swaged, welded, roll threaded or redrawn without fracturing the jacket metal or otherwise exposing the base metal. Thus these new materials can often replace solid nickel, brass or copper wire, or can eliminate the costly post-plating of steel wire forms . . . and with unmatched assurance of coating coverage! Advantages in strength, durability and economy are obvious.

Nickelply, Brassply and Copperply are now available commercially in diameters up to .340". Pertinent data on coating weights, strengths, finishes, base materials, corrosion resistance, etc., are given in Bulletin K-10. Why not send for it now and explore these new possibilities?

*Trade Mark National-Standard Company

NATIONAL-STANDARD COMPANY • NILES, MICHIGAN
Tire Wire, Stainless, Fabricated Braids and Tape

ATHENIA STEEL DIVISION • CLIFTON, N. J.
Flat, High Carbon, Cold Rolled Spring Steel

REYNOLDS WIRE DIVISION • DIXON, ILLINOIS
Industrial Wire Cloth

WAGNER LITHO MACHINERY DIVISION • JERSEY CITY, N. J.
Special Machinery for Metal Decorating

WORCESTER WIRE WORKS DIVISION • WORCESTER, MASS.
Round and Shaped Steel Wire, Small Sizes

ENTHONE "ENSTRIPS"®

can *prevent* this waste!

"ENSTRIPS" – invented and patented by Enthone, Incorporated – are chemical products for dissolving one metal from another, quickly . . . economically . . . without attacking the base. Available for nickel, copper, chromium, zinc, cadmium and silver. For the *right* stripper for *your* needs, write to Enthone, outlining your requirements. Ask for the Enthone "Enstrips" Booklet.

Service Representatives and Stock Points in Principal Cities of U.S.A. and Canada, Brazil, England, France, Sweden, and Germany

ENTHONE INCORPORATED

442 ELM STREET, NEW HAVEN 11, CONNECTICUT

Metal Finishing Processes • Electroplating Chemicals

XVII

This is the seventeenth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Uses of Aluminum in Alloy Steels

Aluminum as an element has been known to chemists and metallurgists for many years. It is never found in nature in its metallic state, being derived chiefly from bauxite, an aluminum hydroxide. Bauxite is present in various parts of the world, including several tropical and semi-tropical regions.

When used in the making of alloy steels, aluminum has several important functions. Because of its great affinity for oxygen, it is a reliable deoxidizer. It produces fine austenitic grain size. And when it is present in amounts of approximately 1 pct, it promotes nitriding. The nitriding process could be described as surface- or case-hardening by means of a nitrogenous medium, or by heating in an atmosphere of ammonia gas and dissociated ammonia mixed in proper proportions.

Other effective agents in producing nitrided cases are chromium, vanadium, tungsten, and molybdenum. As a rule, however, the hardest cases are obtained with aluminum-bearing steels, the nitriding grades being a good example. These are usually steels of medium carbon content with additions of chromium, molybdenum, and sometimes nickel.

Generally speaking, the lower the effective nitriding temperature, the harder the case will be. Aluminum-bearing steels usually show a case-hardness range of 950 to 1150 DPHN (diamond pyramid hardness number). Steels in which no aluminum is present have cases of substantially lower hardness.

If you would care to know more about aluminum as an addition or alloying agent in steels, Bethlehem metallurgists will gladly give you full information. Just write or call us; our technicians are always at your service. They will do everything possible to help make your problems easier. And whenever you need new supplies of alloy steels, remember that Bethlehem manufactures the full range of AISI standard alloy grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I through XVI inclusive, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 16 topics are now available in a convenient 32-page booklet, "Quick Facts About Alloy Steels," and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BOOTH #2661 AT THE SHOW

UNITRON

METALLURGICAL MICROSCOPES

When you visit UNITRON at the Metals Show, you will see for yourself why more and more of our leading industrial firms, universities and research laboratories are turning to UNITRON microscopes. These remarkable instruments have dispelled the myth that unexcelled optical and mechanical performance is inconsistent with low cost.

Even if you are unable to attend the Show, you may have a

FREE 10 DAY TRIAL IN YOUR OWN LABORATORY

by simply requesting the instrument on your company letterhead. There is no cost or obligation and no formal purchase order need be issued. Let the microscope prove its value to you, before you decide to purchase.

UNITRON Metallurgical Microscopes are chosen by such leading firms as . . .

Union Carbide and Carbon
Goodyear Atomic
General Motors
American Smelting and Refining
CBS-Hytron
Sperry Products
Raytheon
Arthur D. Little
Corn Products Refining
Sprague Electric
National Bureau of Standards
International Nickel
Firth Sterling
Raybestos-Manhattan
U.S. Dept. of Agriculture
Colorado School of Mines
General Electric
American Brass
Minneapolis-Honeywell Regulator
Procter & Gamble
Glenn L. Martin Co.
E. I. DuPont de Nemours
International Business Machines
National Cash Register Corp.

THIS COMPLETE CATALOG ON UNITRON MICROSCOPES IS YOURS FOR THE ASKING

This colorful, illustrated catalog gives complete specifications on all of the instruments briefly described on this page, as well as others which we know will interest you. Send coupon below for your free copy.

UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC COMPANY
204-206 MILK STREET · BOSTON 9, MASSACHUSETTS

Please send us your complete catalog on UNITRON Microscopes.

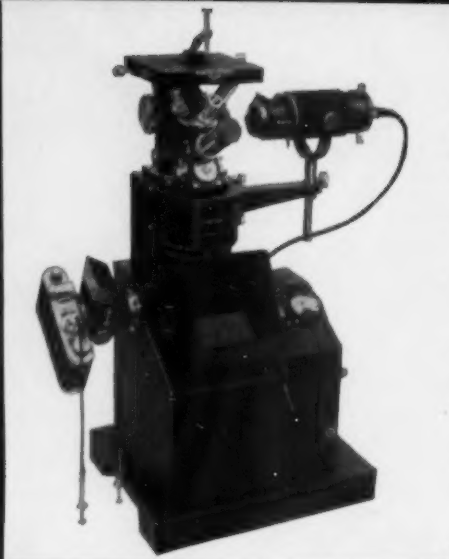
Name...

Title...

Company...

Address..

City........................State........

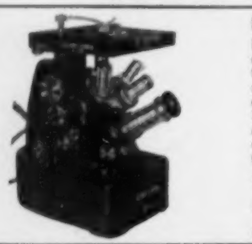


UNITRON METALLOGRAPH and UNIVERSAL CAMERA Microscope, New Model U-11

- For visual observation, measurement, and photography of both opaque and transparent specimens.
- Bright field, dark field, and polarized illumination.
- Revolving nosepiece with 5 objective lenses, 4 photographic eyepieces, 3 visual eyepieces. Coated optics. Magnification range: 25-2000X.
- Compact and entirely self-contained with built-in 3¼" x 4¼" camera, high-intensity illuminator, variable transformer.
- The image is automatically in focus in the camera—transition from observation to photography is instantaneous.
- Transmitted light accessories for transparent specimens included.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Many other important features and accessories including calibrated polarizing apparatus, filters, micrometer eyepieces, film holders, etc. Cabinet.
- Additional accessories include: Polaroid Land Camera attachment; 35 mm camera attachment; low-power (5-40X) objectives; available at extra cost.

COMPLETE UNIT only fob Boston **$1145.**

BINOCULAR MODEL, BU-11 only $1319.



UNITRON Model MEC

is of the inverted type and designed for visual observation of metals, ores, minerals, etc. It includes many of the features of the Model U-11 Metallograph which are connected with visual observation of opaque specimens. 25-1500X.

- transformer built into microscope base.
- vertical illuminator with iris diaphragm.
- coarse and fine focusing.
- filters: polaroid, frosted, blue, green, yellow.
- large mechanical stage with graduated circular rotatable stage plate.
- calibrated polarizing apparatus.
- coated optics
- revolving nosepiece with objectives 5X, 10X, 40X, 100X oil.
- eyepieces: P5X, Micrometer 10X, K15X.

COMPLETE only fob Boston **$319.**

Binocular Model, only $493.

UNITRON TOOLMAKERS and METALLURGICAL

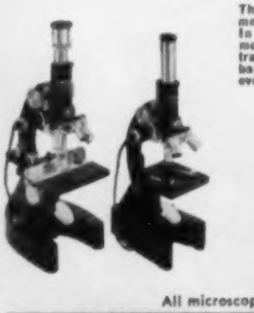
UNITRON Model TM combines in one stand a toolmakers microscope for precise shop measurements of either opaque or transparent specimens and a metallurgical microscope for the high-power examination of polished metal specimens. Note the many features of this versatile instrument.

- combination rectangular 1" x 1" ball bearing stage and circular rotary stage
- large micrometer drums read directly to 0.0001"
- dial indicator measures depth, reading to 0.0001"
- substage illuminator for viewing profiles
- surface illuminator
- vertical illuminator for examining grain structure
- transformer built into base
- inclinable tool holder
- coarse and fine focusing
- revolving nosepiece with objectives: 3X, 10X, 40X. Crossline eyepiece, 10X

Complete only **$1050.**

UNITRON MODELS MMU and MMA

These popular laboratory microscopes are ideal for the examination of both metal and transparent specimens under both ordinary and polarized light. In addition to providing vertical incident light, the illuminator may be mounted directly on the stage for oblique lighting and below the stage for transmitted light. The transformer is located conveniently in the microscope base. These models include features found only in instruments selling for over twice our unusually low prices.



MODEL MMU

- coarse and fine focusing
- focusable stage
- calibrated drawtube
- revolving nosepiece—objectives 5X, 10X, 40X, 100X oil
- eyepieces: P5X, P10X, K15X

Complete only **$287.**

MODEL MMA

- single focusing control
- revolving nosepiece with objectives 5X, 10X, 40X
- eyepieces: H5X, P10X, K15X

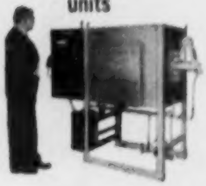
Complete only **$149.**

All microscope prices are subject to change without notice.

UNITRON INSTRUMENT DIVISION OF UNITED SCIENTIFIC COMPANY
204-206 MILK STREET · BOSTON 9, MASSACHUSETTS

from — *to*

small "package" units



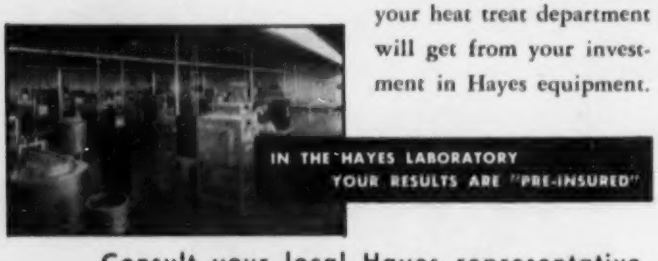
large forging furnaces

Hayes "Certain Curtain" spans the field of

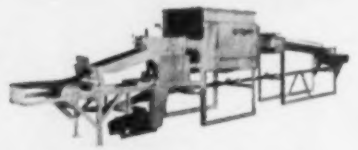
CONTROLLED-ATMOSPHERE ELECTRIC FURNACES

. . . and offers the famous "Pre-insured" Purchase

Over fifty years experience in old and new fields of heat treatment gives Hayes the know-how to help solve your heat treat furnace requirements. Our laboratory and technicians assist in developing the correct heat treatment for your samples. This "pre-insures" your purchase: proves BEFORE you buy, exactly what results your heat treat department will get from your investment in Hayes equipment.



IN THE HAYES LABORATORY YOUR RESULTS ARE "PRE-INSURED"



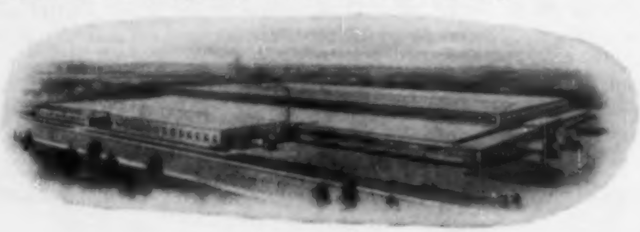
Only Hayes Humpback has "ABD" High-production Feature

Our famous "Humpback" Furnace is widely imitated . . . but no other offers our patented AUXILIARY Belt Drive, which is absolutely necessary to *High Production;* enabling the furnace to turn out several times more work than with ordinary belt drives.

Consult your local Hayes representative. Request new 1956 Catalog.

C.I. HAYES, Inc.

ELECTRIC CERTAIN CURTAIN FURNACES



887 Wellington Avenue, Cranston 10, R. I. Electric Heating Equipment Since 1905


OUT
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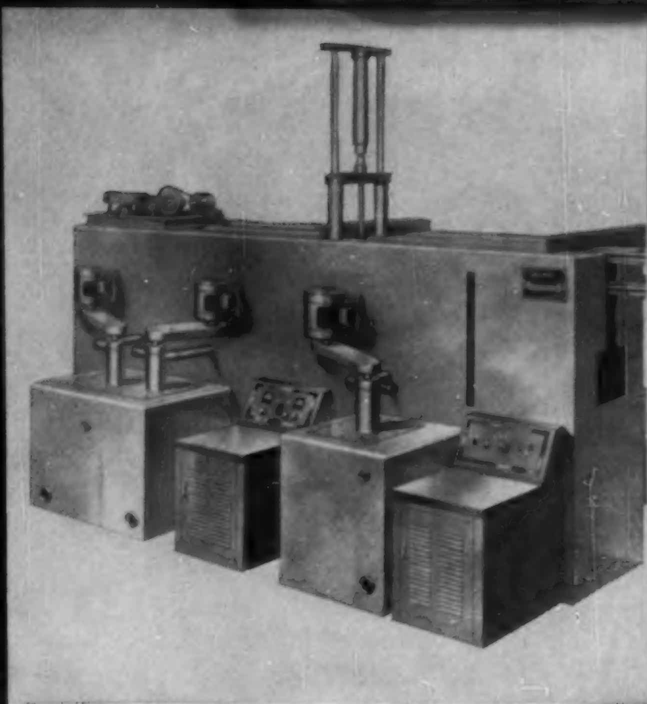
The new Bendix Unitized Ultrasonic Cleaner



The new Ransohoff Conveyorized Cleaning System

NOTHING CLEANS SO CLEAN AS THE BENDIX ULTRASONIC CLEANER—SELECTED BY RANSOHOFF FOR USE IN ITS NEW CONVEYORIZED CLEANING SYSTEM

The experience of several hundred users has demonstrated conclusively that Bendix Ultrasonic cleaning is far faster, far cheaper, and three to seven times more effective than any other method of cleaning parts and assemblies.

Grease, lapping compounds, cutting oils, abrasives, and other contaminants that can be troublesome to parts and assembly performance are *removed 99.5% to 100%* . . . in *seconds.*

Of prime interest today, users' reports show that Bendix Ultrasonics reduces cleaning costs drastically. Direct labor savings amount to as much as 75%. Rejects, due to the presence of contamination, become practically non-existent. Savings from using water-detergent solutions, instead of expensive solvents, frequently run 90% . . . and more.

How are all these benefits possible? Because for the first time a revolutionary . . . and better . . . cleaning principle has been successfully applied to today's volume cleaning jobs. Bendix high-frequency sound waves "break loose" contamination from metal parts and assemblies as no other method can. These Bendix "scrubbing fingers" easily reach into tiny crevices, blind holes and other areas too complicated for other cleaning methods to touch.

And now Ransohoff, Inc., a foremost builder of cleaning machinery, offers industry *a fully-automated ultrasonic cleaning system* that applies the Bendix Ultrasonic Cleaner in a five-stage Ransohoff production line conveyor.

See both new units for the first time at the Metals Show!

Don't miss the system in action at the Ransohoff booth. Visit the Bendix booth for a complete picture of the many different ways that ultrasonic cleaning is helping industry today. PIONEER-CENTRAL DIVISION, BENDIX AVIATION CORPORATION, DAVENPORT, IOWA.

West Coast Office: 117 E. Providencia, Burbank, Calif. Southwest Distributor: Southwestern Eng. & Equip. Co., 3906 Lemmon Avenue, Dallas, Texas. Export Sales and Service: Bendix International Division, 205 E. 42nd Street, New York 17, New York. Canadian Distributor: Williams & Wilson, Ltd., 11 Front Street, East, Toronto, Canada.

See CONVEYORIZED ULTRASONICS IN ACTION
at the
NATIONAL METAL EXPOSITION
CLEVELAND, OCT. 8—12
Ransohoff: Booth 2734 Bendix: Booth 2123

Pioneer-Central Division Bendix AVIATION CORPORATION

TITANIUM STRIP is descaled continuously on time cycles as low as 30 seconds, with excellent results.

10-MINUTE IMMERSION loosens scale on 5 tons of stainless wire. A water quench, 3-minute acid dip, and final water rinse produce a clean, bright surface with no pitting or etching.

Use this fast, safe Hooker Process for descaling steel and titanium

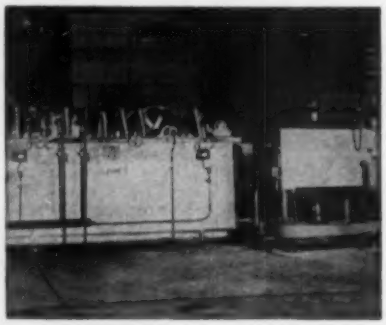
Descale alloy steels and titanium in any form—rapidly, safely—using the Hooker Process with Virgo® Descaling Salt.

A bath of molten Virgo Descaling Salt quickly converts scale, rust, and other surface impurities to an acid-soluble coating. A quench, acid dip, and final spraying then remove this coating in from one-tenth to one-hundredth the usual pickling time, with no measurable effect on the base metal.

You can easily set up the Hooker Process for batch or continuous operation on any form of work including strip, sheets, bars, wire, tubes, plate, castings, forgings, and fabricated parts. You can usually process work as fast as your handling methods allow, with a minimum of supervision. Operation is safe for personnel, and there is little or no spent-acid disposal problem.

You can profit by the experience of more than 50 companies now using the Hooker Process successfully to speed up descaling of alloy steels and titanium in practically every form.

You'll get quick service on any descaling problem, by writing or phoning us. Complete test and engineering facilities are at your disposal, without obligation.



LIGHT-GAUGE ALLOY STRIP is descaled at 20-35 ft. per min. in this Virgo bath, after annealing.

Send for these bulletins—Get the whole story on Virgo Descaling Salt for alloy steels and titanium . . . how the Hooker Process works, its advantages, how to set up a Virgo descaling line, and the services you enjoy as a user. No obligation. Write us today.

HOOKER CHEMICALS

From the Salt of the Earth

HOOKER ELECTROCHEMICAL COMPANY

405 Forty-seventh St., Niagara Falls, N. Y.

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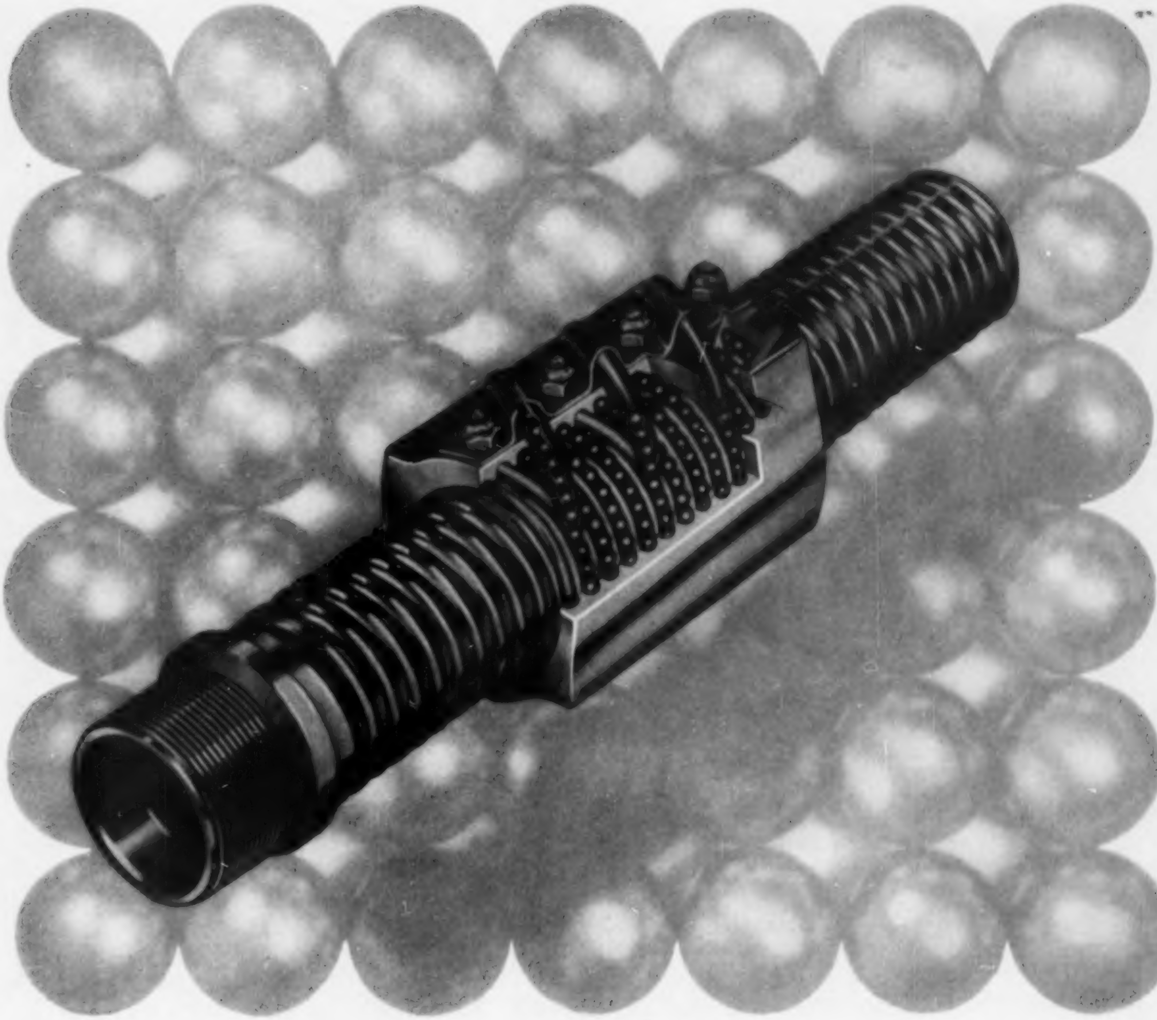
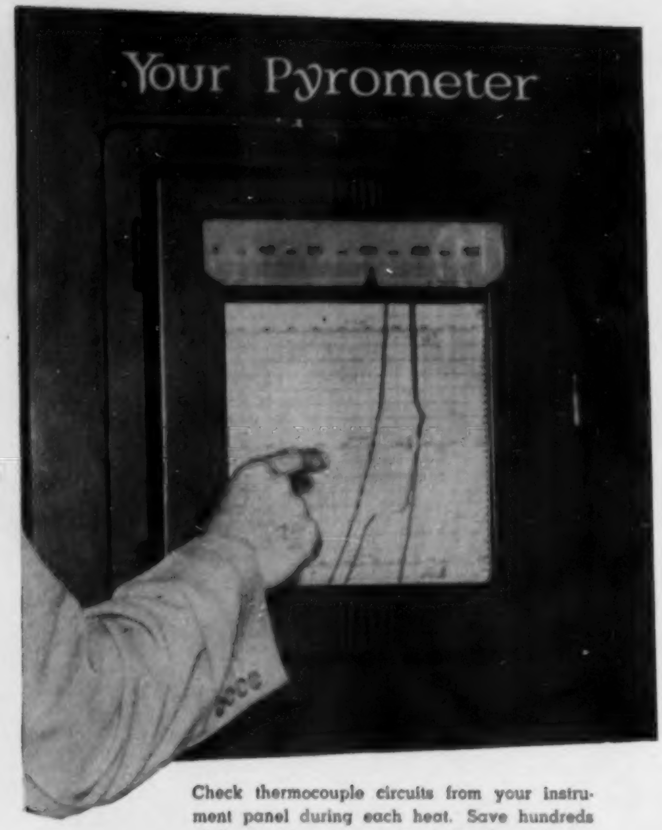




Check thermocouple circuits from your instrument panel during each heat. Save hundreds of hours inspecting and needlessly replacing thermocouples.

THERMOCOUPLE CIRCUIT RESTORER

CUTS INSPECTION and REPLACEMENT COSTS

Listed below are some purchasers of the Restorer* and Leak-Checker.**

BELL ANNEALING FURNACE	Allegheny Ludlum Steel Corp. Rome Strip Steel Co., Inc. Sharon Steel Corp.
BOX ANNEALING FURNACE	American Chain Division American Chain & Cable Co., Inc. Frazer & Jones Co.
CONTINUOUS ANNEALING FURNACE	Damascus Tube Co. Washington Steel Corp.
SALTBATH	Aircraft-Marine Products, Inc. The Electric Auto-Lite Co.
OTHERS	Battelle Memorial Institute Davison Chemical Company Div. of W. R. Grace & Co. Farrel-Birmingham Company, Inc. Ferriot Brothers, Inc. Johnson Bronze Co. U. S. Atomic Energy Commission

***THE RESTORER** detects and corrects thermocouple circuit failure during any heat treating or melting operation.

****THE LEAK-CHECKER** detects leaks in thermocouple protection tubes immersed in saltbath or other melting furnaces.

Write for Catalog R-26

Electronics Division

THE Peerless-Electric® COMPANY

W. MARKET ST. · WARREN, OHIO

FANS · BLOWERS · MOTORS

ELECTRONIC EQUIPMENT

Since 1893

Visit Booth No. 706 at the Metal Show

SPOTCHECK PINPOINTS DANGER AREAS in heavy machinery and operating equipment. The Spotcheck dye penetrant inspection kit is excellent for testing during maintenance, or for intermittent spot testing for cracks and other surface defects. Kit contains all materials in easy-to-use pressurized spray cans plus a handy, lightweight carrying case.

NOW YOU CAN "SEE" DEFECTS in wires, rods and tubes of low conductivity metals such as aluminum, tungsten or uranium. The FW-200 Series unit sets up eddy-currents in the test materials. Using frequencies from 15 KC to 2 MC, any cracks, splits or seams are detected and easy-to-read indications are shown on the TV-type picture tube. Diameter changes register separately. Adjustments can be made for a visible signal and automatic rejection of defective materials.

HALLMARK OF QUALITY IN NONDESTRUCTIVE TEST SYSTEMS

Write for complete details concerning any of the above case studies, or ask for our new booklet on "Lower Manufacturing Costs."

Case Studies: NONDESTRUCTIVE TESTING SYSTEMS

Type ZA-29 Zyglo unit is widely used and accepted for detecting surface defects in aluminum magnesium, brass and titanium parts.

How Production, Payroll and Public Relations Can Benefit from "Early-Stage" Testing

The most for the least, that's what your customers want today. To help answer these demands and still show a profit, you can increase the output and quality of production without increasing costs and facilities.

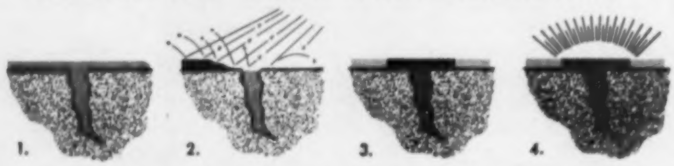
By supplying process control and by maintaining consistent quality standards, Magnaflux nondestructive testing systems provide a quick, accurate, economical production tool. They can increase output and lower your operating costs. M methods save money by keeping production at a dependable level.

M methods provide an "early-stage" test for the detection of surface defects in all magnetic and non-magnetic metals, ceramics, glass and other solid materials. "Early-stage" testing pinpoints improper procedures and corrective steps can be taken to eliminate the manufacture of defective parts. Where serious defects do occur, parts can be rejected before further effort is wasted on additional processing. When defects are minor, repairs can be made to decrease scrap losses and upgrade salvage operations.

"Early-stage" testing with M methods pays in many ways. It increases usable production output, it prevents unnecessary payroll costs on defective materials, it protects your reputation by insuring consistent quality, all of which means dollar savings to you!

Find out how low-cost Magnaflux nondestructive test methods can help protect your company's quality, pocketbook and name. Write, or call on a Magnaflux testing systems engineer today.

HOW ZYGLO FINDS CRACKS IN NON-MAGNETIC PARTS



1. A surface film of Zyglo penetrant is applied to parts by dipping, spraying or brushing. After this application, penetrant enters any surface opening, cracks or pores, and excess penetrant is allowed to drain off. 2. Parts are then washed with a water spray, and permitted to dry.

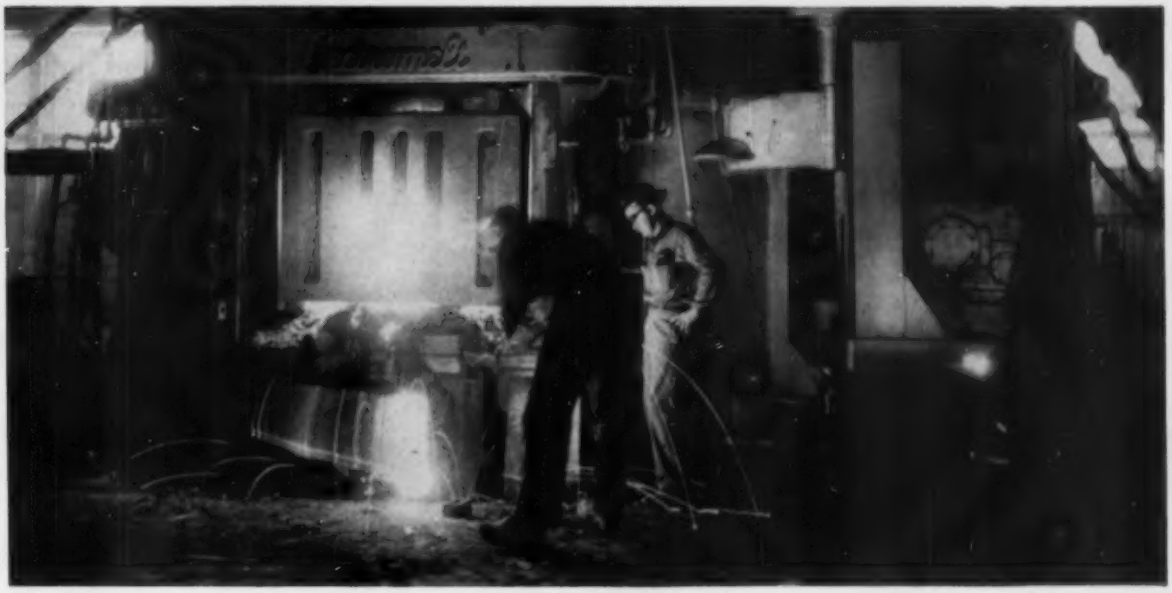
3. Next, parts are dipped in a developing powder. This acts as a blotter, and draws the penetrant to the surface. 4. Look at the part under "black light". Any crack or surface defect will show up as a glowing fluorescent indication that is impossible to miss. Scratches will not be shown.

Take Your Inspection Problems to the House of Answers

MAGNAFLUX CORPORATION

7346 West Lawrence Avenue • Chicago 31, Illinois

New York 36 • Pittsburgh 36 • Cleveland 15 • Detroit 11 • Dallas 19 • Los Angeles 58



Sample is poured into small mold. Test piece is sent to chemical laboratory through a pneumatic tube for complete analysis.

Strict Quality Control Required in Production of Stainless Steels for Critical Applications

Testing Process at Rotary Electric Steel Co. Continues through Each Step in Manufacture

Rotary Electric Steel at Detroit produces the high quality stainless and alloy steels needed for the automotive, aircraft, chemical, anti-friction bearing, and food-handling equipment industries, as well as for critical defense applications. Precise quality control and constant inspection at each processing step is basic in Rotary's production.

Raw Material

Testing starts even before the steel is in a molten state. The raw material for the electric furnace steels that Rotary produces is not ore, but steel scrap of the highest quality, to which is added various high-grade alloying elements. Quality control starts with the careful selection and grading of the scrap.

Melt Shop

Frequent samples are taken during the melting process and sent to the chemical laboratory for analysis. Several determinations are made on a direct-reading spectrometer that enables a report on the chemical analysis to be made in minutes. Additional tests insure that the steel meets customer specifications. Before the steel is poured from the furnace the chemical laboratory approves the heat.

Processing

Tests are made at progressive stages of the processing. Chemical analyses are taken and samples submitted to the metallurgical department for additional tests as required, such as etch tests, tensile tests, magnaflux tests, and cleanliness ratings. Quality control at Rotary means that every order of steel shipped has had metallurgical approval as well as final physical inspection.

New Color Brochure

"How Steel Is Made at Rotary," an informative 4-color booklet, can be obtained by writing Rotary Electric Steel Co., Box 4606, Detroit 34, Michigan. Rotary has sales offices and agents in Detroit, Indianapolis, Newark, N.J., Cleveland, and Chicago.

SELECTION GUIDE FOR BRAZING FURNACES

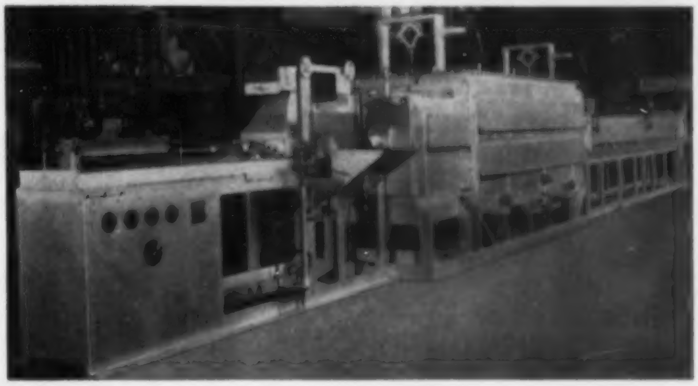
Check These Standard HARPER Controlled-Atmosphere Brazing Furnaces Against Your Requirements

☐ **CONTINUOUS MESH BELT FURNACE**

The perfect production furnace for brazing versatility. Provides adjustable speed automatic conveyance, precluding need for special fixtures, trays, etc. Ideal for silver or copper brazing of short runs on different shapes. Belt loading up to 10 pounds per square foot at 2100°F., larger loads permitted at lower temperatures. Belt widths to 24", charge heights to 12"; production capacities to 550 lbs/hr. Completely automatic operation available.

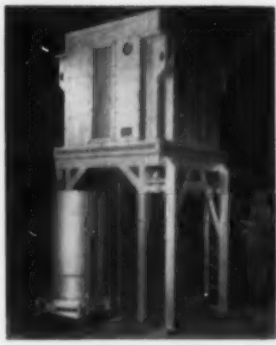
☐ **CONTINUOUS PUSHER FURNACE**

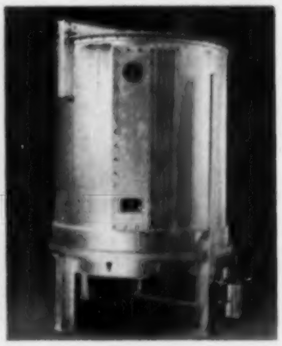
The mechanical pusher furnace is designed for heavier loading (up to 100 pounds per square foot) and is therefore most suitable for large-production silver or copper brazing runs of heavier assemblies. Trays or special fixtures often used. Provides accurate atmosphere control. Pilot plant or small production units available for manual pusher operation. Standard hot zone sizes up to 18" x 9"; production capacities to 1000 lbs/hr.



☐ **ELEVATOR FURNACE**

The best batch brazing furnace where maximum heat uniformity is important. Hearth is rolled away from furnace for easy loading, is repositioned under furnace, then raised into heating chamber. Ideal for large and/or heavy loads which must remain free of vibration during brazing. Adaptable to stainless steel brazing when muffle is used. Rapid cooling obtainable by removing work from furnace chamber. Available chamber sizes up to 150 cu. ft.





☐ **BELL FURNACE**

The bell furnace is similar to the elevator except that the assemblies to be brazed may be stationary throughout the cycle. The load is placed on a fixed hearth and the furnace bell lowered over it. Generally available with nickel alloy heating elements for temperatures up to 2050°F. Special designs may incorporate silicon carbide for higher temperatures. Ideal for stainless work with muffle.

If you want more information on these or other Harper Furnaces, just check the coupon or visit Harper Booth 724 at the Cleveland Metal Show.

Harper — Harper Electric Furnace Corp. — Buffalo, New York

HARPER
ELECTRIC FURNACES
FOR

CONTINUOUS BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, ANNEALING, FORGING and RESEARCH

HARPER ELECTRIC FURNACE CORP.
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Send data on Brazing Furnaces Checked:

☐ Mesh Belt ☐ Elevator ☐ Pusher ☐ Bell

☐ Other ....

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from an
ACCOLOY ENGINEER
BOOTH 936
NATIONAL METAL SHOW
Cleveland–October 8-12
See for yourself the versatile engineering skill that is characteristic of these Heat and Corrosion Resistant Castings.
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ALLOY ENGINEERING & CASTING COMPANY
HEAT RESISTANT CASTINGS
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STAINLESS STEEL CASTINGS
ALLOY CASTING CO. (DIVISION)
CHAMPAIGN, ILLINOIS
ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

See the

RANSBURG No. 2 Process

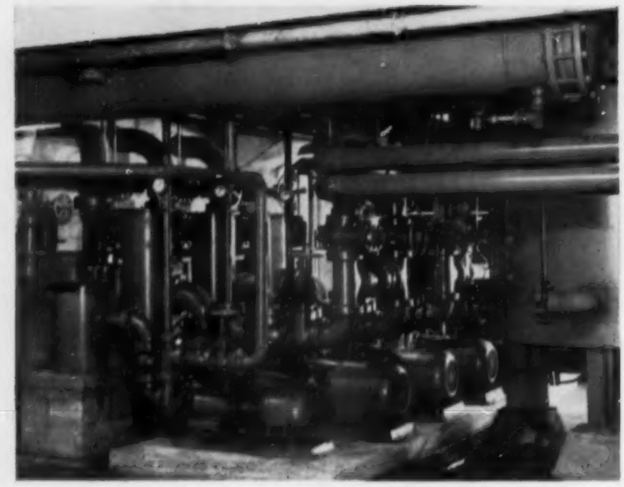
Electrostatic Spray

IN OPERATION AT THE

METAL SHOW

Ransburg representatives will be on hand at all times to tell you about the money saving advantages which can be yours with the No. 2 Process.

Controlled Quenching contributes to "flying box car" safety



Battery of B&G Pumps for circulating quench oil.

Controlled quenching with B&G equipment is an important step in heat treating landing gear struts for Fairchild "Flying Boxcars". It is one of the processes which assure an end product that will stand up under the high stresses and shocks which occur in landing a heavily loaded plane!

This installation is an outstanding example of excellent heat treating and quenching facilities. Most of the equipment is located in a basement with only the tops of the furnaces and quench tanks exposed above the steel plate floor.

The B&G Quench Tanks have a capacity of 1200 gallons. In the tanks, the oil is not only circulated rapidly and agitated but is changed once a minute by high capacity B&G pumps. Quench oil is drawn from storage tanks in the basement and is held at 135°-140°F. by live steam heat exchangers. With the rapid circulation and agitation of the oil, average loads are brought to quench oil temperature in about 15 seconds.

B&G Oil Quenching Systems are available either as component parts for assembly on the job, or as self-contained packages which combine Coolers, Motors, Pumps, Strainers and all controls into single, integrated units. Engineering service is always available.

B&G Quench Tank with B&G Circulating Pump.

Send for Catalog and Simplified Selection Manual

B & G

Hydro-Flo*

OIL QUENCHING SYSTEMS

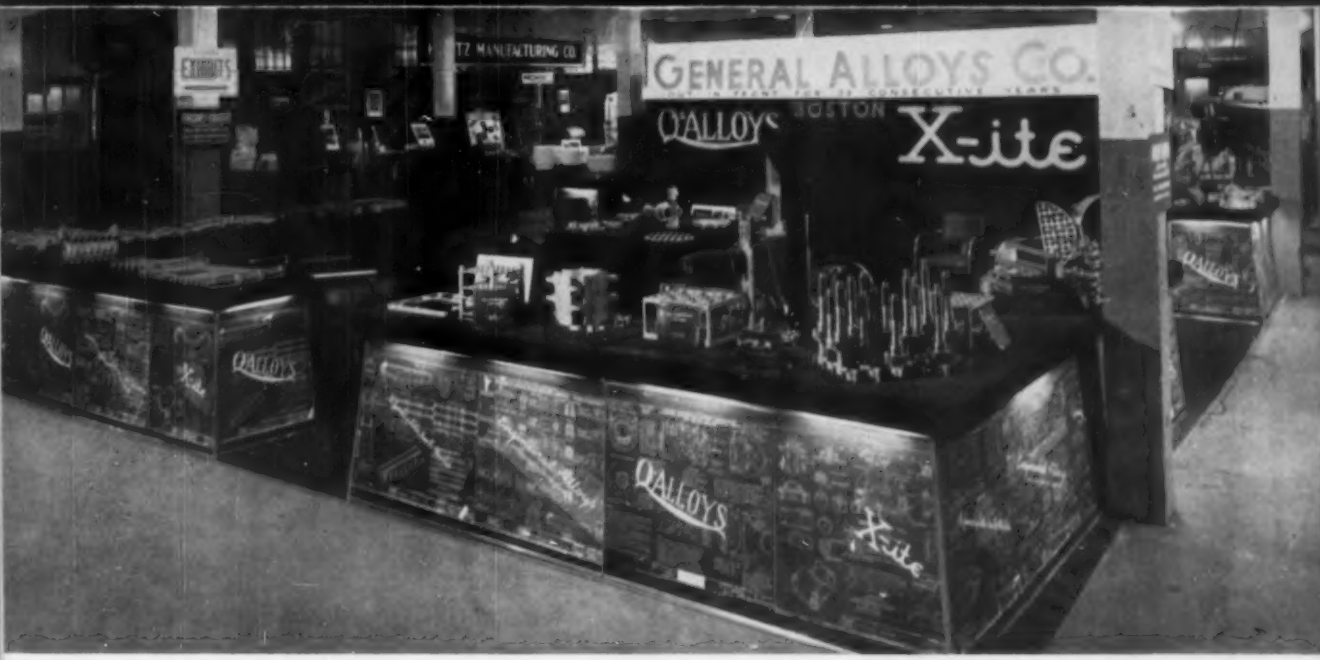
*REG. U.S. PAT. OFF.

BELL & GOSSETT COMPANY

Dept. EM-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong, Ltd., 1400 O'Connor Drive, W. Toronto

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY



Pick two numbers from one to ten and you can get a three and an eight . . .

YES, **38** CONSECUTIVE YEARS

AS USUAL, AT THE MAIN ENTRANCE OF THE

NATIONAL METAL EXPOSITION

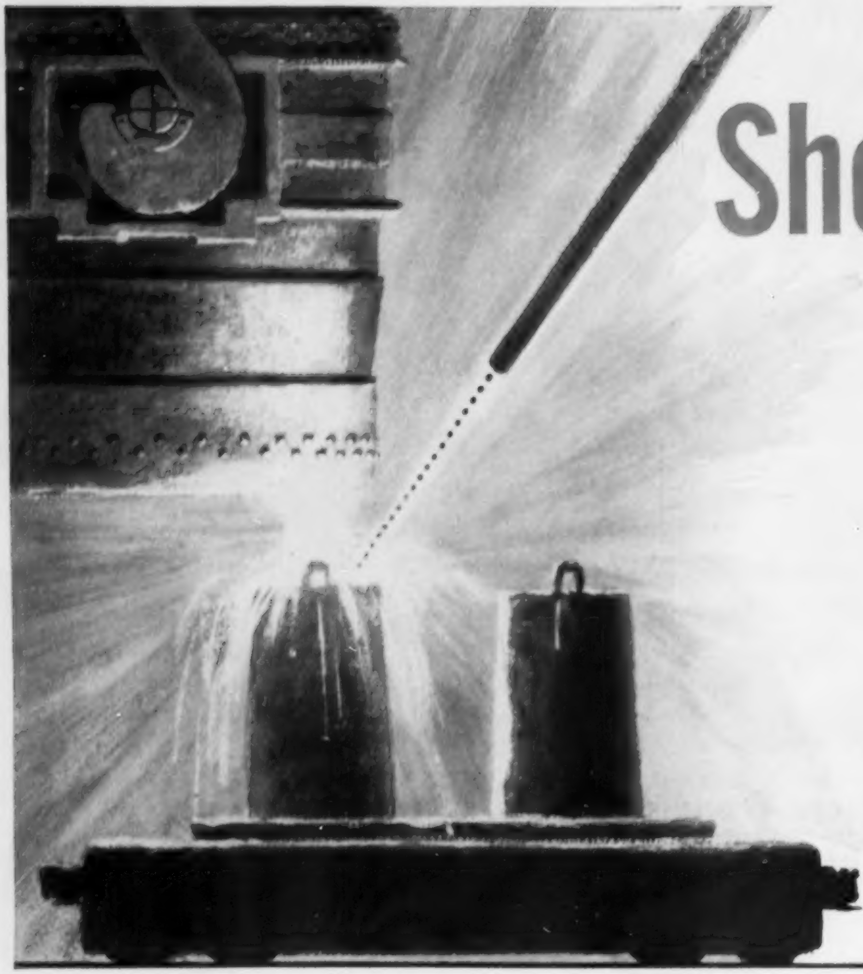
THERE IS NO SUBSTITUTE FOR EXPERIENCE

General Alloys Company is an engineering organization with 38 years experience in the design and manufacture of heat resistant and stainless steel castings. The design of high temperature tooling is our specialty. Consult our specially trained sales engineers in Booth No. 351 at the National Metal Show concerning your alloy problems.

GENERAL ALLOYS COMPANY, BOSTON, MASS.

"OLDEST AND LARGEST EXCLUSIVE MFRS. OF HEAT & CORROSION RESISTANT CASTINGS"

Q'ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite



Shooting lead into steel!

Lead, strange as it may seem, imparts certain desirable machining properties to steel. Leaded steel has been found to be particularly suitable for parts going into business machines, textile machinery, hydraulic fittings, and other equipment where extensive low cost machining is required. Leaded steel in appreciable tonnages is now a part of our big steel output.

At first, the problem of introducing lead into steel and of dispersing it satisfactorily seemed insoluble. Great differences in melting points and in specific gravities tended strongly toward segregation and gas pockets when steel men tried to blend molten steel and molten lead.

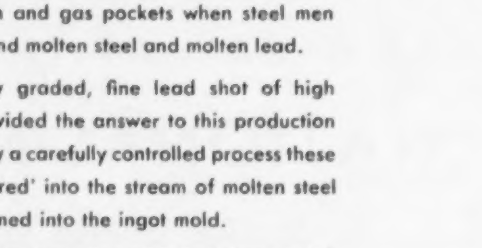
Carefully graded, fine lead shot of high purity provided the answer to this production problem. By a carefully controlled process these shot are 'fired' into the stream of molten steel as it is teemed into the ingot mold.

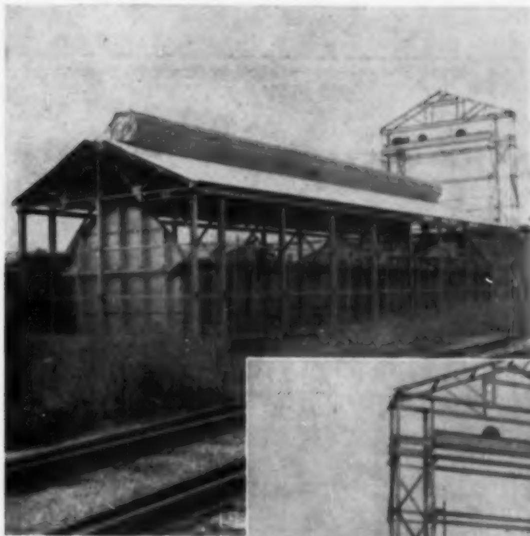
Leaded steels provide added evidence of the usefulness and versatility of the basic metal — LEAD.

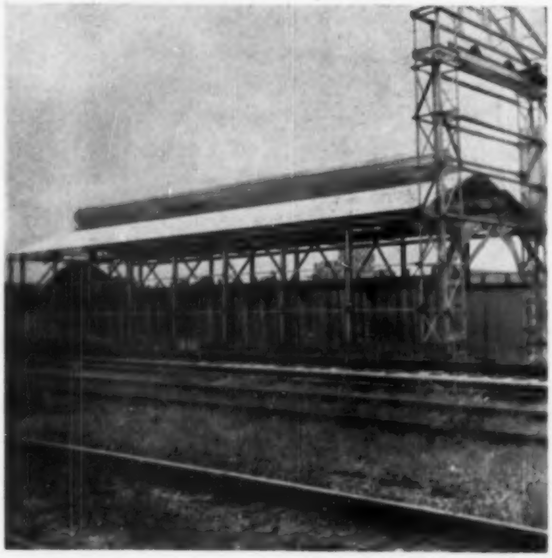
ST. JOSEPH LEAD COMPANY

The Largest Producer of Lead in the United States

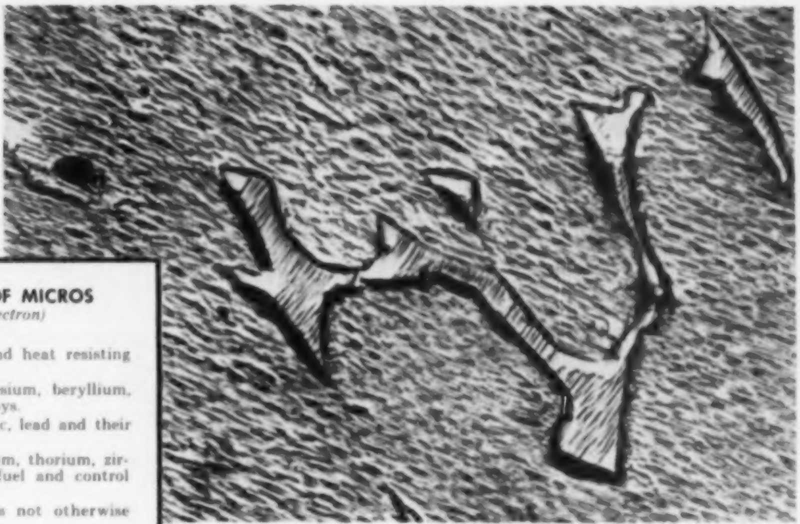
250 PARK AVENUE, NEW YORK 17, NEW YORK







11th Metallographic Exhibit



CLASSIFICATION OF MICROS
(Optical and Electron)

Class 1. Irons and steels.
Class 2. Stainless steels and heat resisting alloys.
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys.
Class 4. Copper, nickel, zinc, lead and their alloys.
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.
Class 6. Metals and alloys not otherwise classified.
Class 7. Series showing transitions or changes during processing.
Class 8. Welds and other joining methods.
Class 9. Surface coatings and surface phenomena.
Class 10. Results by unconventional techniques (other than electron micrographs)
Class 11. Slags, inclusions, refractories, cermets and aggregates
Class 12. Color prints in any of the above classes (no transparencies accepted)

Entries are invited in the 11th ASM Metallographic Exhibit, to be held at the National Metal Exposition in Cleveland, Oct. 6 through 12, 1956.

RULES FOR ENTRANTS

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints should be mounted on stiff cardboard; maximum dimensions 14 by 18 in. (35 by 45 cm.) Heavy, solid frames are unacceptable. Entries should carry a label on the *face* of the mount giving:

Classification of entry
Material, etchant, magnification
Any special information as desired

The name, company affiliation and postal address of the exhibitor should be placed on the *back* of the mount.

Entrants living outside the U. S. A. should send their micrographs by first-class letter mail endorsed "Photo for Exhibition—May be opened for customs inspection".

Exhibits must be delivered before Oct. 1, 1956, either by prepaid express, registered parcel post or first-class letter mail, addressed to:

ASM Metallographic Exhibit
7301 Euclid Ave.
Cleveland 3, Ohio

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1957 if so desired.

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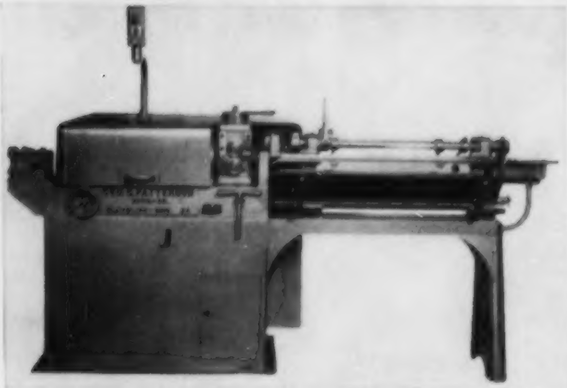

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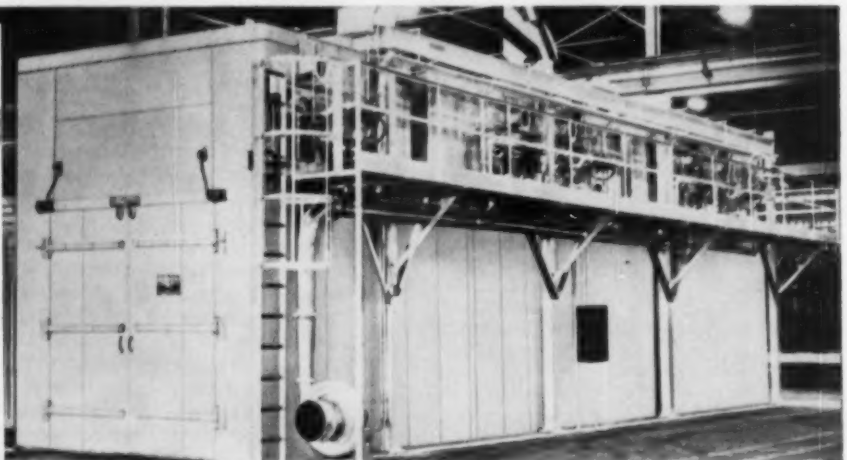

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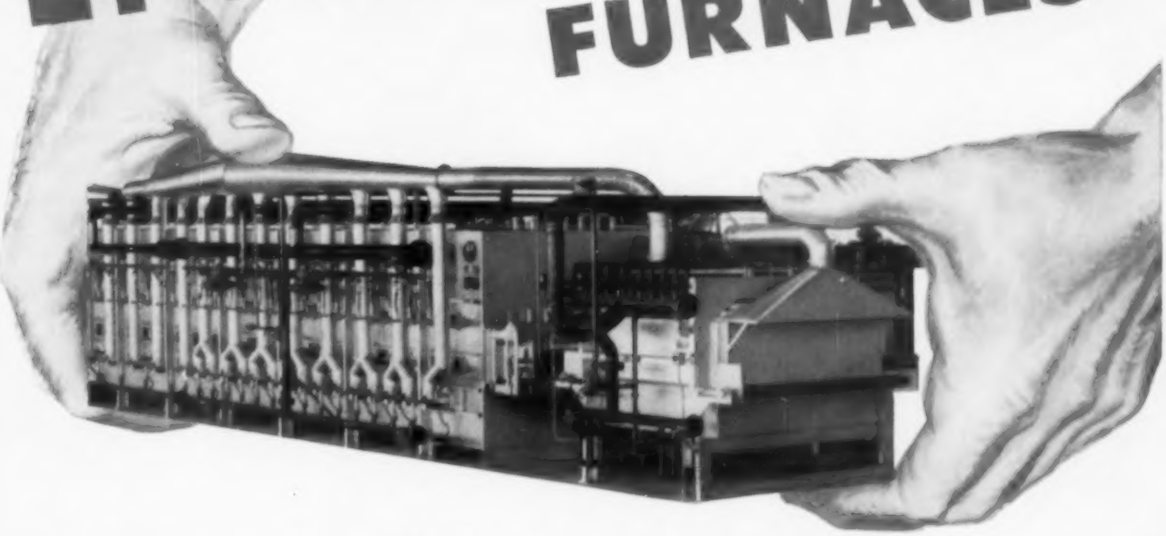

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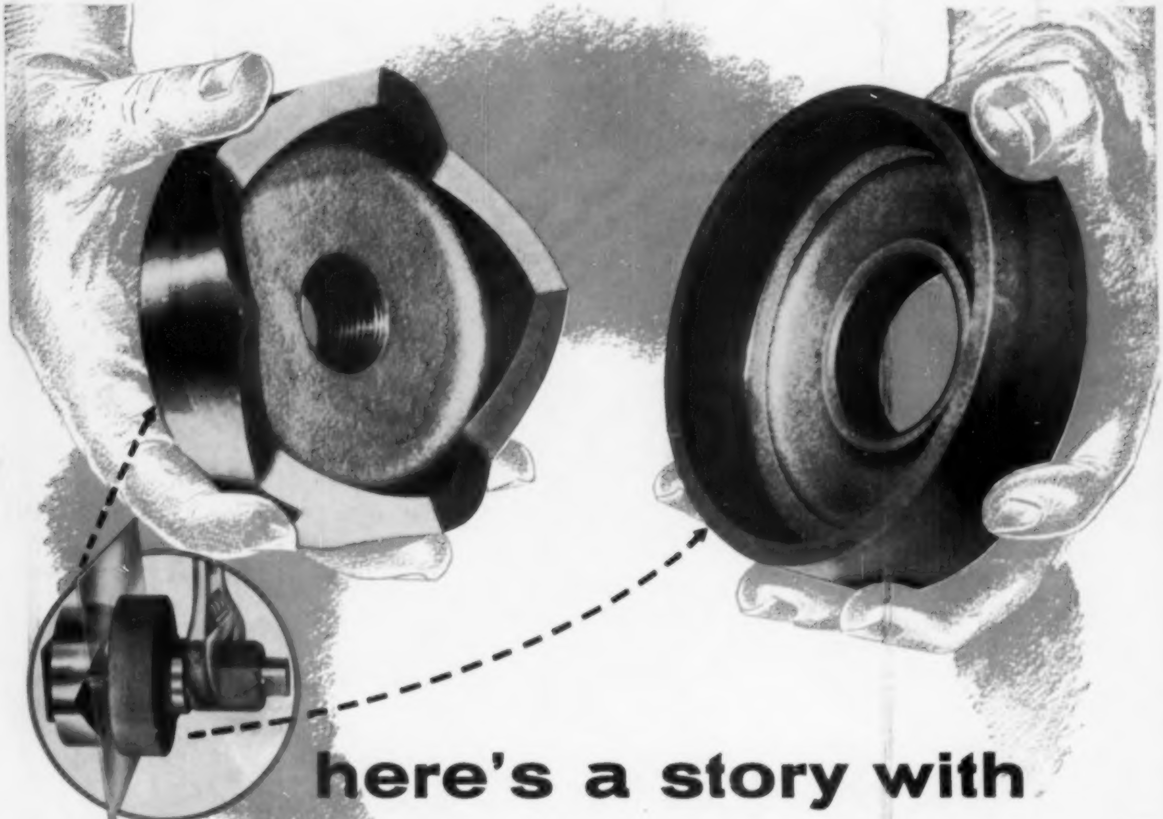

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